KLAMATH RIVER WATER QUALITY 2000 MONITORING PROGRAM
- PROJECT REPORT -

Sponsored by the
U.S. Bureau of Reclamation
Klamath Falls Area Office
with support from
PacifiCorp

Watercourse Engineering, Inc.
Napa, CA 95449

January 25, 2003

The U.S. Bureau of Reclamation contracted with Watercourse Engineering, Inc. (formerly Michael L. Deas, P.E.) to complete various studies in the Klamath River basin with respect to water quality conditions (requisition 00250000022, order number 00pg250021). The studies were intended to support long-term project operations planning as well as environmental and biological studies to determine the impacts of altering Klamath River flows from project operations on Tribal trust resources and listed, proposed, and candidate anadromous fish species under the Endangered Species Act.

Project goals included primarily gathering necessary information to improve characterization of water quality in the Klamath River basin to support existing modeling capability in the mainstem Klamath River between Iron Gate Dam and Seiad Valley. Response to diel changes in key water quality constituents, such as temperature, dissolved oxygen, and nutrient levels were deemed critical to assessing environmental and biological conditions. The project area extended from Link Dam at Upper Klamath Lake to Youngs Bar below the Trinity River, a distance of over 230 river miles. Major tributaries encompassed in the study area included the Shasta, Scott, Salmon, and Trinity Rivers. In cooperation with the U.S. Bureau of Reclamation (USBR), PacifiCorp funded water quality sampling on the mainstem reservoirs (JC Boyle, Copco, and Iron Gate Reservoirs).

The project was designed around several related tasks aimed at further characterizing water quality in the Klamath River while supporting ongoing model development. The tasks included:

- The design, implementation and oversight of water quality monitoring for the 2000 field season
- An update, as necessary, of the existing water quality model for the Klamath River mainstem between Iron Gate Reservoir and Seiad Valley, including calibration and validation of the existing model with new information. Application of the model to identified studies/analyses
- Reporting

These tasks, with the exception of "reporting," are addressed below. The individual programs and their associated subtasks were designed to answer an identified question or to provide information to gain insight into a process or processes in the Klamath River. The nature of such explorations generally spawns additional questions. During the project several issues were brought to light. Examples include identifying the potential value of including censored data (those data points that fall below the laboratory reporting limit) in the final data sets, quantifying the variability among the nearly three dozen water quality probes, relating benthic algae field data to model simulations, etc. In several cases, a decision was made to pursue these questions. The result is that in addition to the monitoring and modeling work, there are a handful of other issues documented and included in the report or in the report appendices. The desire was to broaden the scope of the project and (hopefully) not detract from it.

Design, Implementation, and Management of Water Quality Field Program

The water quality field program was the primary task in the Klamath River Water Quality Studies. The field program consisted of seven inter-related monitoring programs:

- Semi-monthly grab sampling
- Continuous water quality probe (Hydrolab Datasonde) deployment
- Water temperature monitoring
- Benthic algae monitoring
- Three-day synoptic surveys
- Trace elements screening
- Reservoir water quality sampling

As noted above, in addition to these elements PacifiCorp monitored mainstem reservoirs in coordination with USBR. All grab sample work was covered under a single QAPP, SOP, and field sampling schedule. Each program is briefly described below.

Semi-Monthly Grab Samples

The objective of the semimonthly program was to build a data set providing insight to background levels of physical and chemical constituents. Principal constituents included inorganic and organic nitrogen and phosphorous species, biochemical oxygen demand, total dissolved solids (TDS), calcium, magnesium, carbonate and bicarbonate, and chlorophyll a. Grab samples were collected twice per month from May through November at the following locations:
Klamath Reclamation Project area:

- Klamath Straits Drain at Tule Lake Outlet
- Klamath Straits Drain at Stateline
- Klamath Straits Drain at Hwy 97,

Mainstem Klamath River locations:

- Klamath River at Miller Island
- Klamath River near Keno
- Klamath River above Copco Reservoir
- Klamath River below Iron Gate Dam
- Klamath River at Seiad Valley,

Klamath River tributaries:

- Shasta River near mouth
- Scott Rivers near Ft. Jones.

USBR MP-157 assisted in identifying the need and scope of quality assurance for 2000. A quality assurance program plan (QAPP) and standard operating procedures were developed for the grab sampling program.

To accommodate the increased cost of developing and implementing the QAPP, the scope of the sampling program was modified. Certain physical parameters were dropped (e.g., sodium, chloride, manganese), while nutrients were retained and biochemical oxygen demand and chlorophyll a were added. Sampling was shifted from a frequency of every two weeks to twice per month to further reduce costs. Finally, grab sampling at three locations was eliminated: Salmon River near Somes Bar, Trinity River at Hoopa, and Klamath River Youngs Bar. The impetus for dropping these sites was based on limited existing data and the fact that only one mainstem Klamath River site was included between Seiad Valley (river mile 129) and the Pacific Ocean. It was decided to focus above Seiad Valley and seek funding for a more comprehensive/intensive monitoring program for the lower river in subsequent years.

USBR funded USFWS to provide field support for the lower river sites (from Klamath River above Copco Reservoir to Seiad Valley. All field crews were trained by MP-157 and support for field personnel was available throughout the season. External QA samples consisting of a blank, spike, duplicate, and rinseate blank were incorporated into the grab sample program. Overall, sampling and lab results were good for all parameters except chlorophyll a. The processing lab was unable to produce results with a reporting limit less than 40 ug/l (desired reporting limit was <5 ug/l), although they worked throughout much of the field season to improve their methods.

All data have undergone validation by MP-157 and season summary reports for all data and the associated laboratories are included herein. The data was further processed to

- Estimate values below the reporting limit,
- Provide summary statistics (e.g., maximum, minimum, mean, standard deviation),
- Formulate exceedance probabilities (figures) for each site,
- Graphically depict the data on a site by site and date with error bars representing the range of variation consistent with the QAPP.

Field and processed data are included in a separate data appendix

Datasonde Deployment

Hydrolab Datasonde (Datasonde) water quality probes were used to record physical parameters at 1-hour intervals at 13 sites in the basin. Parameters included temperature, dissolved oxygen, pH, specific conductance and redox potential (not all probes). Probes were deployed at all grab sample sites, as well the Klamath River at Youngs Bar and in the Salmon River near Somes Bar and Trinity River at Hoopa. USBR provided funding to the Hoopa and Yurok tribes to assist in deployment, retrieval of Datasondes at Youngs Bar and for the Trinity River near Hoopa. The Datasonde in the Salmon River was serviced by the USFWS.

Previous water quality deployment efforts led to several changes in 2000. Probes were exchanged weekly and were shipped to and from Klamath Falls. All calibration and downloading took place in Klamath Falls. Biolfouling of the dissolved oxygen membrane was a problem at nearly all monitoring locations, sometimes occurring within 48 hours of deployment. Certain measures were taken in an attempt to minimize the biofouling including cleaning the probes thoroughly after each download. A shorter deployment time was discussed (3 and 4 day exchange frequency), but the shipping costs as well as increased field and in-house staff time were prohibitive. Field deployment and in-house calibration and maintenance protocols were formalized (attached herein) to ensure the best possible results from the probes. Still, variation among instruments was common. To quantify the variation among instruments (and individual probes) a "probe population" test was conceived wherein all probes were subject to equivalent environmental conditions and the results compared. The results of this test identified probes that consistently reported high or low values as well as quantify the variation or range of reported values. The average value of the parameter (T_w, DO, pH, specific conductance) based on all instruments was assumed to represent "actual" environmental conditions. Standard deviation was used to illustrate variance among instruments. The test was carried out prior to field season and upon completion of the field season. Most probes performed well, i.e., were within factory specifications, but dissolved oxygen and pH for many instruments ranged beyond factory specifications. All results are presented in the appendices.

To ease interpretation of the data given the variability identified in the aforementioned probe population test, efforts were made to keep the same probes at each sampling location. Due to the extensive amount of data, each location is only presented in graphical form in the data appendix. The tabular (numerical) data is included on the data CD. These data are raw data. The only processing that took place was to remove those periods of time when the probes were not in the water. Using this data requires a review of the probe population test data, as well as consideration of in-field conditions (i.e., biofouling).

Water Temperature

There was a desire to collect additional physical parameters in the river reach between Iron Gate Dam and Seiad Valley, but resource limitations precluded the acquisition and deployment of additional probes. However, a cost effective method of collecting water temperature data was implemented wherein remote logging thermistors (Onset Corporation Stowaway®) were deployed at Cottonwood Creek, above the Shasta River; at Walker Road Bridge, above the Scott River; and Scott River at mouth. Site locations were determined based on previous studies and field monitoring efforts completed by various agencies and organizations. Because grab sampling and a Datasonde deployment occurred in the Scott River at the USGS gage near Ft. Jones (over 20 miles upstream from the confluence with the Klamath River), a temperature logger was deployed at the mouth to determine if temperature varied between the gage and the mouth. Comparison of the records did indicate that differences occurred, especially in the spring.

These remote logging devices record temperatures to ±0.2°C (0.38°F), and were downloaded at approximately 2 month intervals. All loggers were tested prior to deployment to ensure proper operation. Loggers were deployed in metal canisters (3-inch pipe) attached to shore with stainless steel cables.

Benthic Algae Monitoring

The impetus to monitoring benthic algae in the Klamath River was a direct result of previous water quality modeling efforts on the Klamath River, wherein limited algae data were available. The initial investigation was to monitor growth of algae with artificial substrate. Unglazed ceramic tiles were deployed in the river in March for a test period at three locations: below Iron Gate Dam, above Cottonwood Creek, and near the Shasta River. The site below the Shasta River was not used in the field study because of topographic and riparian shading that was inconsistent with the other two sites.

The principal finding of the test period was that grazing is an important issue. At the Cottonwood Creek site snails grazed the tiles clean. Although no grazing was apparent at Iron Gate Dam, it was decided to deploy floating periphyton samplers to minimize the impact of grazing. Three periphyton samplers (8 microscope slides each) were deployed at each site and monitored for two 4-week periods in June and August. The unglazed ceramic tiles were maintained to qualitatively address grazing and other benthic impacts. Microscope slides from the floating periphyton samplers were randomly sampled at intervals that ranged from 3 to 8 days. Detached, drifting filamentous algae (e.g., macrophytes) often fouled the samplers. This problem was overcome to a large extent by placing a t-post upstream of the samplers, effectively capturing much of the debris.

Three slides were processed individually for dry weight and ash free weight, and one slide was processed for chlorophyll a. Additionally, a sample from one collection effort was submitted for algal speciation/identification. Twelve species of diatoms were present (typical of periphyton). The dominant species tended to favor conditions with a fairly high nutrient content. Algal growth rates varied among the two sampling sites and periods. Results of these data as they pertain to model simulations are discussed below.

The floating periphyton samplers only reflect a portion of the algal assemblage in the Klamath River below Iron Gate Dam. Though periphyton is readily seen on the river bed, several other types of algae are apparent. Most visible are the large filamentous forms dominated by *Cladophora* and *Potamogeton*. Further work is required to more completely characterize this complex fraction of the aquatic system.

Synoptic Survey

Previous studies suggested that during certain times of the day and certain seasons nitrogen species (ammonia and nitrate) might be limiting to algal growth. To ascertain sub-daily water quality conditions several synoptic water quality surveys were designed and implemented to augment the semimonthly grab sampling program and Datasonde deployment. Three synoptic surveys were completed between Iron Gate Dam and Seiad Valley during the months of June, August, and September. Two of the three synoptic surveys (June 5-7 and August 7-9) included grab sampling three-times per day for three days and the deployment of additional Datasondes. The sampling locations were:

- Klamath River below Iron Gate Dam
- Klamath River above Shasta River
- Shasta River near mouth
- Klamath River above Scott River
- Scott Rivers near mouth
- Klamath River at Seiad Valley,

The grab sample parameters included ammonia, total Kjeldahl, nitrate plus nitrite, total phosphorous, orthophosphate. In addition, two filtered samples at each site were colle cted: organic phosphorous and organic nitrogen. The purpose of the latter samples was to identify how much of the total organic nitrogen and phosphorous fractions were in dissolved form and presumably immediately bio-available for primary production. Data suggest that under most circumstances the majority of the organic nitrogen and phosphorous was in dissolved (versus particulate) form. Datasondes were deployed at the same locations specified for grab samples and hourly water temperature, dissolved oxygen, pH, specific conductance, and redox.

The September 26-29, 2000 synoptic survey was completed using only Datasondes. A third grab sampling effort was not deemed economical. Preliminary lab results illustrated that the there were modest variations in nutrient concentrations throughout the course of a day, but significant variations were not clearly apparent. One notable finding was the variation in nutrient concentrations between the June and August synoptic surveys. During the June survey, the data suggest that nitrogen was in short supply; while in August this was not the case. Phosphorous (as orthophosphate) levels in August were roughly half of the levels found in June.

The synoptic sampling programs were designed to coincide with the semimonthly sampling program to allow a broader (spatial) representation of water quality conditions, as well as use limited resources more economically.

Trace Elements

The 1998 and 1999 program sampled for selected metals that are deemed important to aquatic life: lead, cadmium, zinc, and copper. However, there are many additional metals and other trace elements that have potentially deleterious effects on aquatic systems. Although this component of the sampling program was not directly related to modeling, it was retained due to its potential importance in water quality conditions in the basin. After conferring with several entities, including USGS (Portland) and the North Coast Regional Water Quality Control Board, it was decided to expand the sampling from 4 metals to 15 trace elements. To accommodate the increased number of constituents and associated costs, the sampling frequency was reduced to four times during the field season (based roughly on project operations). Monitoring occurred at the following sites:

- Link Dam
- Klamath Straits Drain at Hwy 97
- Klamath River near Keno
- Klamath River below Iron Gate Dam

Sampling was completed on May 23, June 20, July 25, and September 26, 2000. The dates were selected based on discussions with USBR staff and are intended to reflect conditions prior to, during, and near the end of irrigation season. Trace elements that were monitored included:

Aluminum	Antimony	Arsenic
Cadmium	Chromium	Copper
Iron	Lead	Magnesium
Mercury	Nickel	Selenium
Silver	Thallium	Zinc

Hardness data, as represented by calcium and magnesium, were collected coincident with these samples because several freshwater aquatic life (FAL) criteria are functions of hardness. Mercury and aluminum were above FAL criteria on multiple occasions at nearly all sites. Silver and lead exceeded FAL criteria on a few occasions. The QAPP required a different grade of bottle be employed after minor contamination was discovered.

Mainstem Reservoirs

The work completed by PacifiCorp in JC Boyle, Copco, and Iron Gate Reservoirs provided a critical link between the river reaches. The impoundment of water in and operations of these reservoirs can affect downstream river reaches.

PacifiCorp completed grab sampling and profiles of physical parameters on approximately a monthly basis for JC Boyle, Copco, and Iron Gate Reservoirs. Physical parameters included water temperature, dissolved oxygen, pH, and specific conductance. Secchi depth was also measured during field visits. Principal grab sample constituents included inorganic and organic nitrogen and phosphorous species, biochemical oxygen demand, and chlorophyll a. External QA samples consisting of a blank, spike, duplicate, and rinseate blank were incorporated into the grab sample program. Overall, sampling and lab results were good for all parameters except chlorophyll a (as noted above, the lab was unable to reproduce the desired reporting limit).

In addition to grab samples and physical profiles, PacifiCorp also placed remote logging thermistors suspended from cables attached to the booms in the aforementioned reservoirs, as well as Keno Reservoir. These temperature loggers recorded on hourly intervals and provide a much more comprehensive picture of the reservoirs when compared with the monthly profile data.

Some of the concerns that existed in the field monitoring program were not an issue in the reservoir work. Biofouling of the water quality probes did not occur because deployment was not continuous and regular maintenance kept probes in good condition. Likewise shipping probes to and from Klamath Falls was not a factor, as PacifiCorp was responsible for their own probes.

Grab sampling was done in concert with USBR, with USBR providing support for external QA spikes, as well as miscellaneous field materials as necessary.

Model Assessment and Application

Model Assessment

One component of the project was updating, as necessary, the existing water quality model for the Klamath River mainstem between Iron Gate Reservoir and Seiad Valley. This included an investigation for improving representation of benthic algae in the model as well as incorporating year 2000 data in model calibration and validation. During the benthic algae monitoring study it became readily apparent that the Klamath River benthic community was not only extremely complex, but also poorly understood. The sampling effort provided the first concrete values on growth rates, and the dynamic processes that were observed in the system. Most notable were grazing by mollusks and invertebrates and the apparent shift of algal species below Iron Gate Dam as the river temperature changed. Further, respiration rate, another model parameter was not measured.

To further evaluate the options for representing benthic algae in simulation models a literature review was completed (see attached appendix). The findings identify important parameters in modeling benthic algae, associated biomass, dissolved oxygen and nutrient effects, and the overall importance of benthic communities. Fundamentally, rivers are different environments than lakes, wherein phytoplankton (free floating) algae typically dominate. The relatively fast moving water of river systems with short residence times prove a challenge to modelers aiming to represent these processes. Selected water quality models currently available include logic to represent benthic algae; however, they are all limited in their ability to characterize the diversity of benthic communities and their complexity and dynamics.

The current model, RMA-11, presumes that algae grow in accordance with a growth rate, respiration (and mortality) rate, and are limited by light and nutrients. Nutrient limitation is based on inorganic nitrogen and phosphorous forms (the role of silica with respect to diatom growth in the Klamath River system is unknown). This fairly simple formulation incorporates only a single "bulk" community (represented by one set of parameters, i.e., it does not look at individual species) and does not directly account for losses by grazing, scour, senescence and sloughing, etc. Further, the selected initial conditions can affect simulated algal biomass at future time steps. Nonetheless, the model has provided considerable insight into the potential dynamics of primary production on water quality conditions in the Klamath River between Iron Gate Dam and Seiad Valley.

There are models available that provide a wider range of input parameters to represent the benthic community and its response on water quality. However, these models often require a large amount of data, or include simplifications of other processes that make them infeasible for most practical applications. Gathering information on the benthic community at a sufficient number of locations over a long period (e.g., spring through fall) would be required.

One available methodology may provide improved results with modest data collection costs, and at a minimum would provide additional data to the existing formulation. The general model representations follow a similar vein to that presented in RMA-11, that is the representation of a bulk community, but in this methodology algal biomass is calibrated to dissolved oxygen concentrations under steady-state conditions. Using a simulation model algal biomass is estimated consistent with dissolved oxygen observations and algal photosynthesis. Respiration rates are calculated based on the estimated algal mass accounting for stream re-aeration. Some models accommodate grazing and sloughing as well. By calibrating to dissolved oxygen the model aggregates all benthic processes into a "bulk" community. The limitation of the methodology is that it is most readily adaptable to steady-state conditions, while the conditions of interest in many cases are highly dynamic. Nonetheless, with systematic data collection over a broad reach of river, it is plausible that sufficient data could be gathered to represent a dynamic system response in space and time. Any such water quality study should include a corresponding ecological component to characterize the flora and fauna of the benthic community.

Model Application

The models and model output were used for various studies during the project period. The principal studies included examining the temperature impact of flow changes in the Klamath River below Iron Gate Dam during summer months. Three studies were completed; the first examined a specific flow change during the late summer and early fall months (August and September), the second looked at a broader range of flows and cumulative effects over the June through September period, and the third revisited benthic algae dynamics in the river system below Iron Gate Dam. Because the first two model applications were predominately limited to water temperature response and the third application was exploratory, water quality calibration was not revisited at this time (the model is already calibrated for temperature).

Late Summer and Early Fall Flow Change: Iron Gate Dam to Seiad Valley

Temperature dynamics in the Klamath River below Iron Gate Dam are affected by quantity of release from upstream reservoirs, regulation of releases to the Klamath River, and tributary contributions. Thus, varying the flow releases to the River at Iron Gate Dam can directly influence water temperature through increased transit time, varied depth and width, and altering the impact of tributary contributions. Model simulations illustrate that daily maximum temperatures are greater at a flow rate of 1030 cfs than at 1330 cfs for all days of the month – up to 1°C (1.8°F) greater at Seiad Valley. Daily minimum temperatures at Seiad Valley are lower at a flow rate of 1030 cfs than at 1330 cfs for all days of the month – up to 0.8°C (1.4°F) lower. The lower flow rate has a longer transit time – on the order of 6 to 8 hours longer between Iron Gate Dam and Seiad Valley. With shorter days and longer nights, the smaller thermal mass and depth associated with the 1030 cfs flow rate allows the river to heat and cool at a more rapid rate, leading to greater diurnal temperature swings in the river (~1.3°C / 2.3°F). Daily mean data tend to mask these conditions, thus hourly simulations were implemented. Flow changes (i.e., withdrawal rate) have the potential to affect the thermal structure of Iron Gate Reservoir as well.

It is apparent that reduced flows can lead to increases in mean daily water temperatures. However, short-term meteorological conditions play a significant role. Clear sky conditions can result in increased daily mean temperatures on the order of a few tenths of a degree Celsius between Iron Gate Dam and Seiad Valley for a flow change from 1330 cfs to 1030 cfs. However, when conditions cool (e.g., cold front), such as can occur during September, the lower flow scenario exhibits cooler water temperatures. The lower flow rate leads to extended exposure to cool conditions, and the smaller thermal mass cools more quickly.

Impact of Normal, Dry, and Critically Dry Hydrological conditions on Water Temperature: June – September: Iron Gate Dam to Seiad Valley

Temperature dynamics in the Klamath River below Iron Gate Dam are affected by upstream reservoirs, local meteorological conditions, regulation and quantity of release at Iron Gate Dam, and tributary contributions. Some principal findings include:

- Under drought conditions tributary contributions are typically small.
- Under typical summer time flows, re-regulation produces predictable "nodes" of minimum temperature variation separated by a one-day travel time in the river (at mean velocity). This phenomenon, apparent in sub-daily data and simulations, are critical in interpreting sub-daily water temperature information.
- Seasonal changes are apparent in the system as well as short-term climatic meteorological conditions.
- Iron Gate Reservoir (and possibly Copco Reservoir) affect the thermal regime of the downstream river in three principle ways (under current operating conditions):
    - In mid-to late spring Iron Gate Dam releases are often slightly below equilibrium temperature, maintaining a slight cool water "benefit" for releases to the Klamath River.
    - In summer, there is minimal cool water benefit to the Iron Gate release (with respect to anadromous fishes). The release is only marginally below equilibrium temperature; however, the release does moderate the daily maximum and minimum temperature.
    - In fall, for short periods, the Iron Gate release can be warmer than equilibrium temperature. Under such conditions, the release is a heat source to the river. This condition is probably short lived.

Dissolved oxygen (DO) dynamics in the Klamath River below Iron Gate Dam were also simulated. The response of DO in the river downstream of Iron Gate Dam is a complex function of flow, release water quality, and primary production. A few notable findings suggest that:

- Simulated mean daily dissolved oxygen (as depicted in longitudinal profiles) is fairly constant throughout most of the summer throughout the river reach. However, in the fall, DO releases from Iron Gate dam begin to decrease to levels well below saturation.
- Further examination of the daily mean DO profiles illustrates that there is potentially appreciable primary production immediately below Iron Gate Dam, shown by a slightly increased daily mean DO.
- Examination of the simulated time series suggests that seasonally (and spatially) primary production directly and appreciably impacts sub-daily dissolved oxygen levels.
- The various flow regimes had a modest impact on daily mean DO concentration. The lower flows did produce a slightly higher mean daily DO, possibly due to increased aeration at shallower depths. Sub-daily data were more highly variable between alternatives, but these data have not been critically assessed at this time to provide an explanation for this response.

Simulated dissolved oxygen results have not been used in any quantitative manner. However, several of the above results are supported by field data.

Benthic Algae Simulations

The flow and water quality models RMA-2 and RMA-11, respectively, were applied under various conditions with the benthic algae logic described by Deas and Orlob (1999). The findings illustrate a system that is highly dynamic in space and time – results that are consistent with information from the field program. Based on these simulations and the results from the field monitoring program, additional logic to incorporate grazing, sloughing, and other processes that potentially affect benthic algae biomass were not incorporated into the model at this time. Although dissolved oxygen probes were in place during the 2000 field season, there are insufficient data to address the highly spatial variability of algal growth in the system. Further, additional fieldwork is necessary to further quantify photosynthesis and respiration (e.g., completion of light and dark bottle tests in tandem with water quality probes), sloughing studies, and grazing impacts. Upon completion of this data a complete update of the model, including calibration and validation should be undertaken. Recommendations for these studies are included in the report.

Additional work under the modeling task included review of various documents submitted to or prepared by USBR.

2001 Work

The implementation of quality assurance measures (including lab oversight, quality assurance program plan, and standard operating procedures) in 2000 led to a basin wide awareness of the importance of and methods for collecting high quality water quality data in the basin. In March 2001 a meeting was held among the various stakeholders in the basin in an effort to coordinate resources and sampling schedules, ideally leading to a more integrated and more useful data. The basic goals of the meeting were to introduce quality assurance measures, identify entities that would be monitoring in 2001, and coordinate (to the degree possible) sampling efforts to produce a data set that represented basin-wide conditions versus multiple, unrelated data sets. Those in attendance included representatives from the US Bureau of Reclamation, U.S. Fish and Wildlife, U.S. Forest Service, U.S. Bureau of Land Management, U.S. Environmental Protection Agency, California Department of Fish and Game, Hoopa Valley Tribe, Karuk Tribe, Yurok Tribe, California State Water Resources Control Board, North Coast Regional Water Quality Control Board, Oregon Department of Environmental Quality, PacifiCorp, interests from the Shasta, Scott River, and Salmon watersheds.

The USBR agreed to make available the QAPP, SOP, as well as all other monitoring program materials to interested parties. Sampling locations, parameters, and frequencies on a reach-by-reach basis (including the Shasta, Scott, and Salmon Rivers) were identified. Efforts were made to quantify available resources and/or limitations, common sampling days, and potential available personnel. USFWS agreed to transfer all sampling locations to a GIS and produce a map defining the various locations, parameters, and agencies in charge of sampling, as well as support an email list server for communication among participants. An informal group was formed: the Klamath Monitoring and Assessment Group (KMAG).

The outcome of this single meeting is uncertain – sharing of information and active use of the list service was modest – thus it is difficult to assess any level of success or failure. Nonetheless, there was increased communication among certain entities and there is promise that a more formal framework would provide a more uniform level of quality assurance, better coordination among parties, a more useful/valuable “final” or “basin-wide” data set, and increased efficiency/economy with regard to limited resources. For example, USBR and PacifiCorp both agreed to cooperatively continue monitoring through the winter of 2000-2001. Both entities, as well as USFWS have been continuing their water quality monitoring efforts through 2001.

CONCLUSIONS AND RECOMMENDATIONS

The project objective to implement a basin wide program to collect baseline data was achieved. Through the semimonthly grab sampling program, deployment of water quality probes, and deployment of remote logging thermistors (loggers). Sampling was completed inn river reaches as well as within mainstem reservoirs. Additional information was collected through special studies, including algae studies, trace elements sampling, and intensive synoptic water quality surveys. This report presents the data form these programs, the techniques used to process the data, as well as supporting documentation on sampling protocols, quality assurances procedures, and appropriate documentation. Although this report by and large focuses primarily on field data, where analysis was completed or information obtained, attempts were made to document the information and findings.

Several findings and recommendation were identified during the project period and subsequent write-up. These are outlined below without regard to order of importance.

- Implementation of a quality assurance project plan and standard operating procedures (SOP) for field sampling provided consistent monitoring methods and allowed multiple agencies to sample in a consistent manner throughout the basin.
  Recommendation: USBR should maintain a QAPP and SOP for field sampling and seek to extend the application of uniform sampling procedures throughout the basin through sharing of the QAPP and SOP developed jointly by MP-157 and the Klamath Area Office staff.

- Implementation of external quality assurance samples (duplicates, spikes, blanks, and rinseate blanks) provided significantly improved confidence in the laboratory data.
  Recommendation: Although there is a cost associated with external quality assurance both in increased field supplies, additional laboratory samples, and in-house staff time to process the results, these quality assurance samples should be continued.

- Monitoring with DataSondes illustrated that long-term collection of physical parameters is possible, albeit with certain limitations. Dissolved oxygen probes suffered from biofouling in a matter of days at many locations within the river. Additionally, ORP probes showed signs of drift during the week long deployments. The frequency of deploying and retrieving the water quality probes is problematic at a basin-wide scale. Limited resources (personnel) and shipping/transportation schedules restrict the deployments period to roughly a week. Finally, it was apparent that there was variation among the individual instruments when measuring pH, and dissolved oxygen.
  Recommendations:
  - Maintain the DataSonde deployment in selected locations.
  - Maintain Datasonde calibration and maintenance procedures to ensure probes are functioning properly and quantify uncertainty associated with individual sensors.
  - Complete pilot studies to determine the time/cost saving associated wherein field staff visit the sites more frequently (e.g., every 3 to 4 days) to clean the dissolved oxygen membrane and reduce download frequency to two weeks. Certain locations require a boat and increasing site visit frequency may be infeasible.
  - Consider a pilot study to determine if completing Winkler titrations may assist in correcting dissolved oxygen data that have been affected by biofouling.
  - Testing the instruments in a single body of water prior to and at the end of each field season can quantify variation among probes. With regard to DataSonde testing, it is recommended that a more rigorous statistical analysis be completed on the results.

- Coordination among multiple agencies can greatly improve the understanding of water quality conditions and response in large basins such as the Klamath River. Reclamation worked with PacifiCorp, the United States Forest Service, and the Yurok Tribe during the 2000 sampling season. In early 2001, and attempt was made to coordinate monitoring within the basin between Link Dam and the Pacific Ocean, including all major tributaries (Shasta, Scott, and Salmon Rivers). The objective of coordination was to identify consistent sampling locations and times, reduce redundant monitoring, identify available resources, introduce a minimum level of quality assurance and standard operating procedures, and share information. Attendance during the April 2001 coordination meeting held at US Fish and Wildlife Service was attended by over 40 people representing nearly every federal, state, tribal, and watershed group in the basin. Nonetheless, without funding the volunteer effort failed to successfully meet the objectives outlined above. Recommendation: Reclamation should seek to pursue coordination when opportunities arise. To some degree this has been done: Reclamation has shared the QAPP and SOP developed during the 2000 monitoring effort with any interested party in the basin. To the extent feasible, the Reclamation should work with other agencies to identify the potential for a basin-wide water quality coordinator position (not within the US Bureau of Reclamation) to encourage basin-wide coordination of monitoring efforts. Such a position, funded by all participants in the basin, would provide a critical role in ensuring that spatial and temporal water quality sampling be completed in a logical and appropriate fashion, that data quality assurance and sampling procedures be standardized, and that well defined methods for data dissemination are adopted. The result would lead to basin-wide water quality data that would be readily comparable across space and time versus the current efforts that are typically redundant, sample different parameters, include variable sampling times and locations, and utilize different analytical or measurement methods.

- All attempts were made to identify sites that were representative of mainstem conditions for the 2000 field sampling program. However, conditions at sampling sites may vary through time and under different hydrologic, meteorological, and water quality conditions.
  Recommendation: Continue to observe conditions at sampling sites and to carry out small-scale studies, as resources allow, characterizing spatial (e.g., lateral and vertical) and temporal variations (e.g., seasonal and/or operational) at existing and proposed sampling sites. Document findings to support sampling methods and to assist in data interpretation.

- The benthic algae survey provided appreciable new information about the benthic flora and fauna. This information was not formally discussed herein primarily because it was much more complex than could be accommodated by the study plan. A brief review of the narrative descriptions of the conditions of the periphyton samplers and the unglazed ceramic tiles suggests that more detailed studies be completed to characterize these important processes.
  Recommendation: Because the primary impetus behind the 2000 field sampling program was to address anadromous fisheries downstream of Iron Gate Dam, and because the benthic flora and fauna play an integral role in the lifecycle of anadromous fisheries, it is recommended that additional work be completed to characterize the benthic community. The spatial and temporal variability of this community no doubt plays a vital role in water quality throughout the system. A comprehensive study defining algal species present, estimates of biomass (e.g., through direct measurement, light and dark bottle test, or other means), identification of mollusks and invertebrate assemblages that graze on algae, and additional growth rate studies should be carried out over multiple field seasons to define the spatial and temporal variability of algae and its potential role in water quality. Reservoir operations, water quality, as well as the fate of phytoplankton (that is washed out of mainstem reservoirs) on downstream river reaches should be included.

- It is not uncommon for water quality monitoring programs to be funded, designed, and implemented, only to find that the field data is not processed and presented in a formal report.
  Recommendation: Data processing and reporting should be an integral part of any sampling program. Data dissemination procedures should be identified early in the sampling program design such that information can be available to interested parties.

- The model simulations provided insight into potential benthic algae dynamics; however, insufficient data are available to completely characterize the water quality response of the various components potentially affecting water quality (e.g., macroinvertebrate or mollusk grazing on benthic algae).
  Recommendation: continue to explore model formulations and approaches to more effectively characterize water quality response within critical reaches of the Klamath River system. This may include specific field studies designing to acquire critical information necessary to characterize physical, chemical, and biological processes. Temporal and spatial characteristics make this a challenging task.

- Field data indicate that mainstem reservoirs experience oxygen concentrations that deviate from saturation. Keno Reservoir, Copco Reservoir, and Iron Gate Reservoir all experience anoxic persistent conditions, which may lead to sediment nutrient release and thus internal nutrient cycling.
  Recommendation: to determine the potential for reduced conditions, oxidation-reduction potential (ORP) should be collected in all mainstem reservoirs when physical profiles are collected with water quality probes (e.g., DataSonde).

- Metals data were collected and are presented herein; however, as a stand alone data set there usefulness is limited.
  Recommendation: Review year 2000 field data in light of other sources of information concerning metals in the Klamath Basin and Klamath Project area.

- Adaptive management is a critical part of aquatic resource management. Although there are many definitions of adaptive management, a pragmatic approach consists of two steps: 1) conduct experiments to increase the knowledge of the system, and 2) plan to change based on the findings of the first step.
  Recommendation: Identify components of the water quality monitoring program, possibly augmented by data or computer simulation models, to assist in adaptive management of water resources in the Klamath Basin.

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

1. KLAMATH BASIN WATER QUALITY MONITORING PROGRAM

The U.S. Bureau of Reclamation contracted with Watercourse Engineering, Inc. (formerly Michael L. Deas, P.E.) to complete various studies in the Klamath River basin with respect to water quality conditions (requisition 00250000022, order number 00pg250021). The studies were intended to support long-term project operations planning as well as environmental and biological studies to determine the impacts of altering Klamath River flows from project operations on Tribal trust resources and listed, proposed, and candidate anadromous fish species under the Endangered Species Act.

Project goals included primarily gathering necessary information to improve characterization of water quality in the Klamath River basin to support existing modeling capability in the mainstem Klamath River between Iron Gate Dam and Seiad Valley. Response to diel changes in key water quality constituents, such as temperature, dissolved oxygen, and nutrient levels were deemed critical to assessing environmental and biological conditions. The project area extended from Link Dam at Upper Klamath Lake to Youngs Bar below the Trinity River, a distance of over 230 river miles. Major tributaries encompassed in the study area included the Shasta, Scott, Salmon, and Trinity Rivers. In cooperation with the U.S. Bureau of Reclamation (USBR), PacifiCorp funded water quality sampling on the mainstem reservoirs (JC Boyle, Copco, and Iron Gate Reservoirs).

The water quality field program was the primary task in the Klamath River Water Quality Studies. The field program consisted of seven inter-related monitoring programs:

- Semi-monthly grab sampling
- Continuous water quality probe (Hydrolab Datasonde) deployment
- Water temperature monitoring
- Benthic algae monitoring
- Three-day synoptic surveys
- Trace elements screening
- Reservoir water quality sampling

As noted above, in addition to these elements PacifiCorp monitored mainstem reservoirs in coordination with USBR. All grab sample work was covered under a single Quality Assurance Project Plan (QAPP), Standard Operating Procedures (SOP), and field sampling schedule. Each element or task is outlined below and includes a "subtask objective." Thus, each task was defined to meet a specific purpose, perceived need, or data gap. However, the task timelines and monitoring efforts were designed to compliment one another. The product is a data set that spans an appreciable section of the Klamath River – from near Klamath Falls to below the Trinity River. Although several efforts were limited to sub-reaches (i.e., Iron Gate Reservoir to Seiad Valley), these efforts provided insight to critical processes that, in certain cases, may be extended to other reaches of the main stem and possibly certain tributaries. Sampling extended from early spring through late fall, including periods when several life stages of anadromous fish are present.

Water quality field monitoring and laboratory protocols were developed for the project to ensure the data set was consistent with the needs of system assessment and anadromous fish restoration objectives. The participating agencies are described below, followed by the description of each program.

1.1 Agency Participation

Several agencies dedicated resources to the water quality monitoring program, including the U.S. Forest Service, Hoopa Tribe, Yurok Tribe, California Department of Fish and Game, and PacifiCorp. The participating agencies, their level of participation, and funding sources are outlined in Table 1-1.

Table 1-1 Participating agencies, contacts, roles and funding source

Agency	Contact	Participation	Funding
US Forest Service: Scott/Salmon River Ranger Districts	Brenda Olson Jim Kilgore	Grab Sample and Datasonde deployment in Middle Klamath Region (Locations: ab. Copco, below Iron Gate Dam, Shasta River, Scott River, and Seiad Valley; Datasonde deployment only at Salmon River	US Bureau of Reclamation
Hoopa Valley Tribe	Tim Hayden Charlie Chamberlein	Datasonde deployment (Location: Trinity River)	US Bureau of Reclamation
Yurok Tribe	James Wroble Clyde Matilton	Datasonde deployment (Location: Young's Bar (Klamath River)	US Bureau of Reclamation
California Department of Fish and Game	Jim Whelan	Benthic algae monitoring, temperature monitoring, local access for Datasonde deployment and grab samples (Locations: Klamath River below Iron Gate Dam and near Cottonwood Creek)	work and supplies: volunteer / laboratory costs: US Bureau of Reclamation
PacifiCorp	Jennifer Kelly	Reservoir monitoring, hydrolab (WQ probe) profiles of physical parameters and WQ grab samples (Location: Iron Gate, Copco, and JC Boyle Reservoirs)	Field work, supplies, and laboratory costs paid by PacifiCorp. US Bureau of Reclamation provided data QA.

Several other groups and individuals assisted in the program either directly or indirectly. In many cases, they provided assistance through access, fielding phone calls, overseeing field equipment or other tasks that made the program possible. They are acknowledged below.

Kim Rushton, California Department of Fish and Game
Dennis Maria, California Department of Fish and Game
Dave Webb, Shasta Coordinated Resource Management Program
Bob and Jan Klingbeil, Global Resources

Finally, the support of U.S. Bureau of Reclamation staff was paramount to the success of the project. We would like to acknowledge the U.S. Bureau of Reclamation staff at the Klamath Area Office for their professional and courteous manner, their commitment to project objectives, and general support. In particular we would like to acknowledge several staff members. Jason Cameron, Bill Wood, and Lisa Hicks played important roles in the coordination and completion of the field sampling program. Their hard work and attention to detail made all components of the field program successful. Jason Cameron was in charge of the field operations throughout the duration of the project. Bill Wood provided support at the inception of the project and was in charge of field supplied for much of the season. Project management was initially assigned to Larry Dugan. His participation and patience were paramount not only in getting the project off the ground, but in his direct participation the portions of the field work. Upon Mr. Dugan's departure, Mark Buettner assumed project management for the latter half of the project. Computer model applications identified herein were completed, with the exception of benthic

algae, under Mr. Buettner's guidance. Michael Berg provided valuable insight into Datasonde performance and calibration procedures. Support from MP-157 was critical to the monitoring program success. John Fields and his staff in Sacramento provided training, assistance in writing the Quality Assurance Program Plan and providing a Standard Operation Procedure for field sampling, laboratory oversight, data validation, and general support. Finally, we would like to acknowledge Bob Davis for his overall support of this project and patience in seeing it through to completion.

1.2 Semi-Monthly Grab Sampling Program

Subtask Objective*: To provide baseline information on main stem and tributary contributions for a representative suite of physical, chemical, and biological water quality constituents. These constituents will be useful in the general characterization of mainstem Klamath River waters, identifying water quality constituents of concern within selected river reaches, and estimating input parameters for water quality models.*

The semi-monthly grab sampling program included 10 locations in the Klamath Basin. The sites ranged from Miller Island (River Mile 246) near Klamath Falls to Seiad Valley (River Mile 128.9). The locations are included in Table 1-2.

Table 1-2 Grab sample locations

	Location	River Mile*
1	Klamath River @ Miller Island	246
2	Klamath Straits Drain (KSD) @ Hwy 97	2.0 (240.5)
3	KSD @ Tule Lake Diversion Tunnel	n/a
4	KSD at State Line (Hwy 161)	n/a
5	Klamath River at Keno Bridge	235
6	Klamath River above Copco Reservoir	208
7	Klamath River below Iron Gate Dam	190.1
8	Shasta River	0.5 (176)
9	Scott River	23.4 (143)
10	Klamath River below Seiad Valley (USGS)	128.9

* River mile for location of tributary-main stem confluence provided in parenthesis

Physical constituents, nutrients, algae (as chlorophyll a), biochemical oxygen demand (BOD), and major ions were examined. Hydrolab water quality probes were used to examine water temperature, dissolved oxygen, pH, specific conductance, and redox at each location when grab samples were taken. The remaining constituents were analyzed under laboratory conditions with the exception of turbidity, which is measured with a field turbidimeter. Table 1-3 summarizes the sampled constituents and method of measurement and Table 1-4 outlines the justification/purpose of each constituent in the sampling program. The selection of constituents was based on review of available data (e.g., 1998 and 1999, see appendices), and budget and resource constraints.

Table 1-3 Grab sample water quality program constituents and methods of determination

	Constituent	Method
Physical	Water temperature	Hydrolab
	Dissolved oxygen	Hydrolab
	pH	Hydrolab
	Specific conductance	Hydrolab
	Redox	Hydrolab
	Turbidity	Turbidimeter
Nutrient	Ammonia	Laboratory
	Nitrate+Nitrite	Laboratory
	Total Kjeldahl nitrogen	Laboratory
	Orthophosphate	Laboratory
	Total phosphorous	Laboratory
Major Ions	TDS	Laboratory
	Calcium	Laboratory
	Magnesium	Laboratory
	Bicarbonate	Laboratory
	Carbonate	Laboratory
Other	Biochemical Oxygen Demand (BOD)	Laboratory
	Chlorophyll a	Laboratory

Although certain constituents do not have direct implications for the health of anadromous fish, several are important in characterizing aquatic systems. For example, carbonate and bicarbonate can be used to determine the alkalinity of a system, defining the degree a system is buffered against changes in pH. Changes in pH have a profound impact on the solubility and toxicity of certain constituents, many of which may be harmful to fish (e.g., ammonia). Likewise, calcium and manganese are often used to estimate hardness. The degree of hardness can affect the response of anadromous fish to various toxicants (e.g., trace metals). Thus, initial water quality assessments usually incorporate a wide range of constituents. Future efforts may focus on specific water quality constituents that are deemed important.

Table 1-4 Grab sampling program constituent justification/purpose

Constituent		Justification/Purpose		
		Critical to Define Aquatic System Condition/Processes	A Direct Limiting Factor for Anadromous Fish	Simulation Model Requirement
Physical	Water temperature	X	X	X
	Dissolved oxygen	X	X	X
	pH	X[a]		
	Specific conductance	X		X
	Redox	X		
	Turbidity	X		
Nutrient	Ammonia	X	X	X
	Nitrate+Nitrite	X		X
	Total Kjeldahl nitrogen	X		X
	Orthophosphate	X		X
	Total phosphorous	X		X
Major Ions	TDS	X		X
	Calcium	X[b]		
	Magnesium	X[b]		
	Bicarbonate	X		
	Carbonate	X		
Other	BOD	X		X
	Chlorophyll a	X		X

[a] Unionized ammonia toxicity is dependent on pH and temperature

b Aquatic life criteria for certain trace elements are dependent on hardness

1.3 Datasonde Deployment

<u>Subtask Objective</u>: Determine sub-daily response of physical constituents for aquatic system characterization and model input.

Continuous recording Hydrolab Datasondes were deployed at 13 locations in the Klamath Basin (Table 1-5). These water quality probes measured and recorded water temperature, dissolved oxygen, pH, specific conductance, and redox at 1-hour intervals. To minimize lost dissolved oxygen (DO) data due to bio-fouling of the DO membrane, probes were deployed for one-week intervals.

The probe deployment provided sub-daily response of water temperature, DO, and pH. These data are critical to interpretation and definition of water quality response throughout the river system. Further, the data provide valuable maximum, minimum, and mean values, as well as the rate of change of constituents. Sub-daily data provides:

<u>Temperature:</u>

- Critical thermal maximum/minimum,
- Day to day persistence of thermal maximum/minimum
- Water management impacts (e.g., downstream impacts of reservoir releases)

<u>Dissolved Oxygen:</u>

- Critical minimum DO and persistence of low DO concentrations,

- Day to day persistence of adverse DO conditions
- Water management impacts (e.g., downstream impacts of reservoir releases)

pH:

- Hourly variation in pH provides insight into role of primary production on water quality
- Can assist in identifying toxicity potential for certain constituents (e.g., ammonia, metals)

Further, the diurnal variation of temperature, DO and pH varies seasonally. These variations are valuable to resource managers from both a biological and operations standpoint. Finally, temperature and DO data (main stem and tributaries) are necessary boundary conditions as well as calibration data for simulation models.

Table 1-5 Datasonde deployment locations

	Location	River Mile*
1	Klamath River @ Miller Island	246
2	Klamath Straits Drain (KSD) @ Hwy 97	2.0 (240.5)
3	KSD @ Tule Lake Diversion Tunnel	n/a
4	KSD at State Line (Hwy 161)	n/a
5	Klamath River at Keno Bridge	235
6	Klamath River above Copco Reservoir	208
7	Klamath River below Iron Gate Dam	190.1
8	Shasta River	0.5 (176)
9	Scott River	23.4 (143)
10	Klamath River below Seiad Valley (USGS)	128.9
11	Salmon River	1.0 (66.0)
12	Trinity River near Hoopa	12.4 (43.5)
13	Klamath River near Youngs Bar	≈ 35

* River mile for location of tributary-main stem confluence provided in parenthesis

1.4 Water Temperature Monitoring

<u>Subtask Objective</u>: *Collect required sub-daily water temperature data to compliment temperature data collected with water quality probes.*

Main stem and tributary water temperature was monitored at five locations in the Klamath River basin to compliment water quality probe data and support simulation modeling. Loggers were programmed to record temperature at 1-hour intervals. Remote loggers deployments included:

- Klamath River at Cottonwood Creek (RM 182)
- Klamath River above Shasta River (RM 176.7)
- Klamath River at Walker Rd. Bridge (RM 156)
- Klamath River above Scott River (RM 143.5)
- Scott River (RM 1)

The temperature logger deployment at the mouth of the Scott River provide insight into the similarity of water temperature between the Datasonde sampling location near Ft. Jones (RM 23.4) and the confluence with the Klamath River (measured at approximately RM 1.0).

1.5 Benthic Algae Sampling

<u>Subtask Objective</u>: *Collect necessary data to more completely quantify impact of primary production downstream of Iron Gate Dam. Estimate potential algae growth rates to support simulation modeling.*

Benthic algae have been identified as a potentially important component of primary production affecting water quality in the mainstem Klamath River below Iron Gate Dam. To develop the requisite model input data (seasonal growth rates) a field-sampling program for benthic algae was implemented. Artificial substrates were deployed at two locations:

- Klamath River below Iron Gate Dam (RM 190)
- Klamath River near Cottonwood Creek (RM 182)

Quantitative and qualitative methods were employed. Floating periphyton samplers and unglazed ceramic tiles were used to assess algae growth conditions. The floating samplers were employed to reduce the impacts of grazing, while the ceramic tiles were placed on the bed to determine the impacts of growth subject to grazing. The algae samples were collected from the floating samplers for laboratory analysis, while the unglazed ceramic tiles provided a qualitative assessment of changes in substrate composition and impacts of grazing.

Two sampling series of four weeks included:

- June 5-29, 2000
- August 8-28, 2000

Samples were gathered at approximately weekly intervals and processed under laboratory conditions to determine chlorophyll a and ash-free dry weight. These data were used in conjunction with narrative descriptions of ceramic tiles.

1.6 Synoptic Water Quality Surveys

<u>Subtask Objective</u>: *Acquire the necessary sub-daily water quality data to explore sub-daily water quality response and support simulation modeling.*

To effectively assess diel dissolved oxygen response of the Klamath River below Iron Gate Dam and to support model application, sub-daily grab samples were collected. An abbreviated set of constituents was sampled during the synoptic surveys; however, the sample set was augmented with dissolved organic forms of nitrogen and phosphorous (Table 1-6).

Table 1-6 Synoptic water quality survey constituents and methods of determination

	Constituent	Method
Physical	Water temperature	Hydrolab
	Dissolved oxygen	Hydrolab
	pH	Hydrolab
	Specific conductance	Hydrolab
	Redox	Hydrolab
Nutrient	Ammonia	Laboratory
	Nitrate+nitrite	Laboratory
	Total Kjeldahl nitrogen	Laboratory
	Orthophosphate	Laboratory
	Total phosphorous	Laboratory
	Organic nitrogen (diss.)	Laboratory
	Organic phosphorous (diss.)	Laboratory

Two surveys were completed in the Klamath River between Iron Gate Dam and Seiad Valley: June 5-7 and August 7-9. A third survey was completed in September incase adverse conditions negatively affected one of the first two surveys. The June and September sampling periods were designed to coincide with periods when juvenile and adult fish, respectively, may occupy the study reach. Early August is typically the most adverse period of the summer for anadromous fish.

Samples were gathered three times per day (6 a.m., 11 a.m. and 4 p.m.) for three days at six sites:

- Klamath River below Iron Gate (RM 190)
- Klamath River above Shasta River (176.7)
- Shasta River (RM 0.0)
- Klamath River above Scott River (RM 143.5)
- Scott River RM (0.1)
- Klamath River below Seiad Valley (RM 128.9)

In addition, Datasondes were deployed at the following locations:

- Klamath River above Shasta River (176.7)
- Klamath River above Scott River (RM 143.5)
- Scott River RM (0.1)

These sub-daily samples provide further insight into the role of nutrient availability and the role of primary production in day-to-day water quality conditions in below Iron Gate Dam.

1.7 Trace Elements Screening

Subtask Objective: Provide a preliminary characterization of trace element concentrations at a selected number of sites within the Klamath Basin.
In addition to the semi-monthly grab samples, trace elements and trace metals were screened at monthly intervals at four locations in the basin. Fifteen elements were included in the screening samples (Table 1-7).

Table 1-7 Trace element screening suite constituents

Aluminum	Antimony	Arsenic
Cadmium	Chromium	Copper
Iron	Lead	Magnesium
Mercury	Nickel	Selenium
Silver	Thallium	Zinc

This broad-based screening was intended to determine baseline levels of trace elements and metals at selected locations and to identify those that may be of concern in the aquatic system. Constituents found to have elevated concentrations were identified for potential future monitoring. The locations and impetus for site selection are outlined in Table 1-8.

Table 1-8 Sampling locations and purpose for trace elements and trace metals screening

Location	Purpose
Klamath River at Link Dam (RM 253)	Quantify releases from Upper Klamath Lake
Klamath Straits Drain at Hwy 97	Quantify outflow from Klamath Project operations
Klamath River at Keno Bridge	Quantify outflow from upper basin
Klamath River bel. Iron Gate Dam	Quantify releases to Klamath River below Iron Gate Dam

1.8 Reservoir Water Quality Sampling

<u>Subtask Objective</u>*: Obtain water quality data (profiles) in mainstem reservoirs between Keno Dam and Iron Gate Dam.*

Because mainstem reservoirs potentially play an important role in the quality of waters released to downstream reaches, reservoir surveys were included in the monitoring program. Specifically, Iron Gate Reservoir (RM 190.2), Copco Reservoir (RM 198), and JC Boyle Reservoir (RM 225) were included in this project. Monitoring consisted of three primary tasks: (1) deployment of temperature loggers at pre-selected depths in the reservoirs; (2) monthly profiles of physical constituents; and (3) water quality grab sampling surveys. Each is outlined below.

<u>Temperature Loggers</u>

Temperature loggers were deployed at selected depths in Iron Gate, Copco, and JC Boyle Reservoir – suspended from the log boom and from upstream of the dam. The loggers recorded at hourly intervals and were downloaded approximately every two months. Loggers were deployed at the surface and every 10 feet in Iron Gate and Copco Reservoir, and at the surface and every 5 feet in JC Boyle. A fourth thermistor string was deployed in Lake Ewauna, upstream of Keno Dam.

<u>Reservoir Profiles</u>

Hydrolab water quality probes were used to conduct monthly profile measurements in each reservoir, commencing in April and concluding in October. Secchi depth was measured at each location. Water temperature, DO, pH, and specific conductance were measured at 1 meter intervals in the photic zone (≈3 times Secchi depth) and at a minimum of 3 meter intervals below the photic zone. Physical constituents sampled in the reservoir profiles are outlined in Table 1-6.

<u>Water Quality Grab Samples</u>

Water quality samples were collected four times in the reservoirs: early May, early June, early August, and mid-September. The early May condition was used to estimate the state of the reservoirs at the beginning of the warming period. The June, August, and September surveys coincided with the river synoptic river surveys, providing three comprehensive synoptic sampling dates for the Klamath River and reservoir system.

Water quality constituents sampled in the reservoirs included nutrients, BOD, and chlorophyll a, as outlined in Table 1-9. Samples were collected at three representative depths in Iron Gate and Copco reservoirs: epilimnion, metalimnion, and hypolimnion. All epilimnion samples were obtained at a depth of 1 meter. Metalimnion and hypolimnion sample depths were estimated from the hydrolab profiles of water temperature. In the relatively shallow JC Boyle Reservoir, two depths were sampled: 1meter and 8 meters.

These data are used to further characterize seasonal system response, assist in interpretation of water quality in downstream river reaches, and in the case of Iron Gate Reservoir will be useful in further calibration, validation, and application of an existing reservoir water quality models.

Table 1-9 Mainstem reservoir water quality survey constituents and methods of determination

	Constituent	Method
Physical	Water temperature	Hydrolab
	Dissolved oxygen	Hydrolab
	pH	Hydrolab
	Specific conductance	Hydrolab
	Redox	Hydrolab
Nutrient	Ammonia	Laboratory
	Nitrate+nitrite	Laboratory
	Total Kjeldahl nitrogen	Laboratory
	Orthophosphate	Laboratory
	Total phosphorous	Laboratory

2. SITE DESCRIPTIONS

The individual site descriptions for all sampling programs are described in the following sections. The methods of sampling and sample processing are outlined and special circumstances noted.

2.1 Klamath River and Klamath Project Semi-Monthly Grab Sample Site Descriptions

The semi-monthly grab sampling component of the Klamath River water quality 2000 program collected samples at 10 locations within the Klamath Project, the mainstem Klamath River, and principal tributaries (Table 2-1). Attributes of each site are presented below. All samples collected "by hand" refer to dipping bottles directly into the river to be filled.

Table 2-1 Semi-monthly grab sampling locations

Sampling Location	Latitude	Longitude
Tule Lake Tunnel Outlet Canal @ Brownell Rd. Bridge	N41° 55.795'	W121° 36.022'
Klamath Straits Drain (KSD) @ Hwy 97	N42° 4.846'	W121° 50.833'
KSD @ Stateline Rd. (Headworks)	N41° 59.804'	W121° 46.676'
Klamath River at Miller Island	N42° 8.821'	W121° 50.904'
Keno Bridge	N42° 7.627'	W121° 55.700'
Klamath River above Copco Reservoir	N41° 57.910'	W122° 15.390'
Klamath River bel. Iron Gate Dam	N41° 55.865'	W122° 26.517'
Shasta River @ USGS Gage	N41° 49.393'	W122° 35.708'
Scott River @ USGS Gage	N41° 38.429'	W123° 0.867'
Klamath R. at Seiad Valley @ USGS Gage	N41° 50.247'	W123° 11.855'

2.1.1. Tule Lake Outlet Canal

The Tule Lake outlet canal was sampled just below the egress from the tunnel, at the Brownell Road Bridge. The location was just upstream of the Lower Klamath National Wildlife Refuge boundary. Samples were collected with a Van Dorn sampler from the center of the bridge and processed with a churnsplitter.

2.1.2. Klamath Straits Drain at Stateline Road

Also known as Klamath Straits Drain at headworks, the Stateline Road site was located off of Highway 161 at the northern edge of the Lower Klamath National Wildlife Refuge. Samples were collected with a Van Dorn near the drain outflow gates and processed with a churnsplitter.

2.1.3. Klamath Straits Drain at Highway 97

The Klamath Straits Drain was sampled west of Highway 97 and the railroad tracks where the F and F-F channels converge to a single channel. Sampling occurred with a Van Dorn or by filling the churnsplitter directly from the drain from the dividing wall between the two channels, drawing from the channel that was actively being used to convey water to the Klamath River. This site was a quality assurance site and thus all samples were processed with a churnsplitter.

2.1.4. Klamath River at Miller Island

Grab samples at Miller Island were collected from the boat dock by hand. Chlorophyll a was collected in the churnsplitter. There was the option to collect a sufficient volume through dipping (filling) the churnsplitter and processing accordingly.

2.1.5. Klamath River at Keno

Samples were collected from the Keno Bridge using a Van Dorn to collect a sufficient volume that was subsequently processed using a churnsplitter.

2.1.6. Klamath River above Copco Reservoir

The Klamath River was sampled above Copco Reservoir about 3 river miles south of the Oregon-California state line. The sampling site was located immediately upstream of Shovel Creek at a summer crossing (seasonal bridge). Samples were collected using a Van Dorn from the bridge and processing in a churnsplitter, or collecting by hand from the bank. Chlorophyll a was always collected in the churnsplitter. Collecting samples from the bridge with a Van Dorn was problematic due to appreciable velocities in this area.

2.1.7. Klamath River below Iron Gate Dam

The Klamath River was sampled approximately 0.4 miles below Iron Gate Dam at a boat launching site immediately downstream of bridge leading to the fish hatchery and powerhouse. When used as a quality assurance site, river water was collected from the bank by dipping (filling) the churnsplitter. When production sampling occurred, samples were collected by hand and chlorophyll a was always collected in the churnsplitter.

2.1.8. Shasta River

Shasta River sampling occurs at the USGS gage, approximately one mile upstream from the mouth (at the gage house, versus the cable crossing). Access is through a locked gate. Samples were collected by hand from the bank and chlorophyll a samples were always collected in the churnsplitter.

2.1.9. Scott River

The Scott River sampling site was located 23.4 miles upstream from the mouth at the northern end of the Scott Valley at the USGS gage. The sampling site was located at the bottom of a steep bank. Samples were collected by hand from the bank. The Scott River was prone to the largest changes in flow of any mainstem and river sites. Chlorophyll a samples were always collected in the churnsplitter.

2.1.10. Klamath River at Seiad Valley USGS Gage

A USGS Gage and cable crossing clearly delineated this sampling site located a few miles below the community of Seiad Valley. This site was moved from an upstream location used during the 1998 and 1999 sampling due to concerns about samples effectively representing mainstem conditions at summer flows. Samples were collected by hand from the bank and chlorophyll a was always collected in the churnsplitter.

2.2. Klamath River Mainstem Reservoir Grab Sample Site Descriptions

Iron Gate, Copco and JC Boyle reservoirs were sampled at multiple depths to characterize the vertical variation within the water column. Keno Reservoir was not included in this program (see temperature monitoring program for Keno Reservoir). Vertical profiles for water temperature, dissolved oxygen, pH, and specific conductance were collected coincident with the grab sampling program at identical locations.

2.2.1. JC Boyle Reservoir

Sampling occurred from a boat at the mid-point of log boom. Samples were collected at three depths on the first visit, but after determining the depth to be approximately 8 meters at this location, sampling depths were reduced to two – at one meter below the surface and roughly 1 meter off the bottom. Samples for the first three visits were collected with a Van Dorn and processed using a churnsplitter. Thereafter, samples were collected with a pump (see QAPP and SOP for details).

2.2.2. Copco Reservoir

Sampling occurred from a boat at the mid-point of log boom. Samples were collected at three depths with one sample each in the epilimnion, metalimnion, and hypolimnion. The depths were at one meter below the surface (epilimnion) roughly 1 meter off the bottom (hypolimnion), and at an intermediate depth based on a temperature profile to define the metalimnion. Samples for the first three visits were collected with a Van Dorn and processed using a churnsplitter. Thereafter, samples were collected with a pump (see QAPP and SOP for details).

2.2.3. Iron Gate Reservoir

Sampling occurred from a boat at the mid-point of log boom. Samples were collected at three depths with one sample each in the epilimnion, metalimnion, and hypolimnion. The depths were at one meter below the surface (epilimnion) roughly 1 meter off the bottom (hypolimnion), and at an intermediate depth based on a temperature profile to define the metalimnion. Samples for the first three visits were collected with a Van Dorn and processed using a churnsplitter. Thereafter, samples were collected with a pump (see QAPP and SOP for details). The epilimnion sample represented the QA site for the reservoir grab sampling program; samples were processed with a churnsplitter.

2.3. Synoptic Study Grab Sample Site Descriptions

Three synoptic surveys were completed during the 2000 field season: June 5-7, August 7-9, and September 26-29. The June and August surveys required grab sampling at six locations (Table 2-2) three times per day (daybreak, late morning, mid afternoon). Two of the sampling locations, Klamath River below Iron Gate Dam and Klamath River at Seiad Valley USGS Gage were coincident with semi-monthly grab sample locations. These two locations were also used as quality assurance sites. Quality assurance samples were only collected during the late-morning sampling. Datasondes were deployed at all locations where grab samples were collected. The September survey consisted only of Datasonde deployment at the selected sites and did not include grab samples. All locations are addressed below with regard to the synoptic sampling event.

Table 2-2 Synoptic study grab sampling locations

Sampling Location	Latitude	Longitude
Klamath River bel. Iron Gate Dam	N41° 55.865’	W122° 26.517’
Klamath River ab. Shasta River	N41° 49.877’	W122° 35.606’
Shasta River @ USGS Gage	N41° 49.393’	W122° 35.708’
Klamath River ab. Scott River	N41° 46.714’	W123° 2.101’
Scott River at Mouth	N41° 46.734’	W123° 2.223’
Klamath R. at Seiad Valley @ USGS Gage	N41° 50.247’	W123° 11.855’

2.3.1. Klamath River below Iron Gate Dam

The Klamath River was sampled approximately 0.4 miles below Iron Gate Dam at a boat launching site immediately downstream of bridge leading to the fish hatchery and powerhouse. This site was used as a quality assurance site for the synoptic survey. When used as a quality assurance site, river water was collected from the bank by dipping (filling) the churnsplitter. When production sampling occurred, samples were collected by hand; the churnsplitter was used to transport sufficient water for filtered samples.

2.3.2. Klamath River above Shasta River

Sampling occurred from the left bank below the remaining foundation of a bridge abutment, immediately downstream of the Highway 263 bridge. Unfiltered samples were collected by hand from the bank; the churnsplitter was used to transport sufficient water for filtered samples.

2.3.3. Shasta River

During the synoptic survey samples were collected at the fish counting weir approximately 0.5 miles downstream of the USGS gaging station. The sampling location was moved to provide efficient processing of multiple samples from multiple locations three times per day. Unfiltered samples were collected by hand from the bank; the churnsplitter was used to transport sufficient water for filtered samples.

2.3.4. Klamath River above Scott River

Synoptic samples were collected approximately 150 feet above the confluence of the Scott and Klamath Rivers on the left bank during the June synoptic survey. Changing river conditions during the August survey required adopting a new sampling site roughly 500 feet upstream of the confluence with the Scott River. Unfiltered samples were collected by hand from the bank; the churnsplitter was used to transport sufficient water for filtered samples.

2.3.5. Scott River

During the synoptic survey samples were collected approximately 100 feet upstream of the confluence with the Klamath River, immediately downstream of the highway 96 bridge. Unfiltered samples were collected by hand from the bank; the churnsplitter was used to transport sufficient water for filtered samples.

2.3.6. Klamath River at Seiad Valley USGS Gage

A USGS Gage and cable crossing clearly delineate this sampling site located a few miles below the community of Seiad Valley. This site was moved from an upstream location used during the 1998 and 1999 sampling due to concerns about samples effectively representing mainstem conditions at summer flows. This site was used as a quality assurance site for the synoptic survey. When used as a quality assurance site, river water was collected from the bank by dipping (filling) the churnsplitter. When production sampling occurred, samples were collected by hand; the churnsplitter was used to transport sufficient water for filtered samples.

2.4. Klamath River and Klamath Project Datasonde Water Quality Probe Sample Site Descriptions

Datasonde water quality probes were deployed at 13 locations in the study area from Miller Island (RM 246) to below the Trinity River at Youngs Bar (RM 35) (Table 2-3). Most sites were coincident with semi-monthly grabs sample sites. In most cases, probes were deployed in an aluminum canister for protection and attached to the bank with a cable and lock to minimize vandalism.

Table 2-3 Water quality probe deployment locations

Sampling Location	Latitude	Longitude
Klamath River at Miller Island	N42° 8.821’	W121° 50.904’
KSD @ Hwy 97	N42° 4.846’	W121° 50.833’
KSD @ Stateline Rd.	N41° 59.804’	W121° 46.676’
KSD @ Tunnel	N41° 55.795’	W121° 36.022’
Keno Bridge	N42° 7.627’	W121° 55.700’
Klamath River above Copco	N41° 57.910’	W122° 15.390’
Klamath River bel. Iron Gate Dam	N41° 55.894’	W122° 26.394’
Shasta River @ USGS Gage	N41° 49.393’	W122° 35.708’
Scott River @ USGS Gage	N41° 38.429’	W123° 0.867’
Klamath R. at Seiad Valley @ USGS Gage	N41° 50.247’	W123° 11.855’
Salmon River	N41° 22.615’	W123° 28.632’
Trinity River	N41° 3.023’	W123° 40.397’
Klamath River at Youngs Bar	N41° 14.797’	W123° 46.398’

2.4.1. Tule Lake Outlet Canal

The probe was deployed in an aluminum canister secured by a cable and lock to the downstream guardrail of the bridge. The probe was suspended from the guardrail so it was at a depth of approximately one meter.

2.4.2. Klamath Straits Drain at Stateline Road

The probe was deployed in an aluminum canister secured by a lock and cable to a fence post on the South East side of the KSD headworks pool. The probe may not have received direct flow when water was released into the KSD headworks pool from the east and west gates of the Wildlife Refuge. The probe was suspended from the fence post so it was not immersed in the sediment (~ 0.3 meters).

2.4.3. Klamath Straits Drain at Highway 97

At the Klamath Straits Drain the probe deployment site was located approximately 0.2 miles west of the grab sample site, where the drain veered north at Wild Horse Butte. The probe was suspended from a buoy without a protective canister at a depth of approximately one meter.

2.4.4. Klamath River at Miller Island

To effectively represent conditions in this reach of river, the water quality probe was deployed in the middle of the channel. It was suspended from a buoy in a protective canister, approximately one meter below the surface.

2.4.5. Klamath River at Keno

Observations at Keno were made from a probe suspended from a buoy to the left of the center support of the Keno Bridge. The off center placement was to avoid conflict with water recreation activities. The probe was suspended without a protective canister, approximately one meter below the surface.

2.4.6. Klamath River above Copco Reservoir

Location was coincident with grab sampling site. The probe was deployed in an aluminum canister secured to a large tree on the left bank by a cable and lock. The probe rested on the river bottom.

2.4.7. Klamath River below Iron Gate Dam

The probe was located approximately 0.2 miles below Iron Gate Dam within the locked gate of the PacifiCorp facilities (for safety reasons) and upstream of the access bridge to the fish hatchery. The probe was deployed in an aluminum canister secured to a large tree on the left bank by a cable and lock. The probe rested on the river bottom.

2.4.8. Shasta River

Location was coincident with grab sampling site. The probe was deployed in an aluminum canister secured to a large tree on the left bank by a cable and lock. The probe rested on the river bottom.

2.4.9. Scott River

Location was coincident with grab sampling site. The probe was deployed in an aluminum canister secured to a large tree on the right bank by a cable and lock. The probe rested on the river bottom.

2.4.10. Klamath River at Seiad Valley USGS Gage

Location was coincident with grab sampling site. The probe was deployed in an aluminum canister secured to a large tree on the right bank by a cable and lock. The probe rested on the river bottom.

2.4.11. Salmon River

At the Salmon River the probe was deployed at the USGS Gage. The gage was approximately one mile upstream from the confluence with the Klamath River. The probe was deployed in an aluminum canister secured to a loop of iron rebar extending from a large block of concrete on the left bank by a cable and lock. The probe rested on the river bottom.

2.4.12. Trinity River

The Trinity River site was likewise at a USGS Gage, in Hoopa. The probe was deployed in an aluminum canister secured to a loop of iron rebar extending from a large block of concrete on the left bank at river mile 12.4 on the Trinity River by a cable and lock. The probe rested on the river bottom.

2.4.13. Klamath River at Youngs Bar

The probe was deployed in an aluminum canister secured to the right bank. The probe rested on the river bottom.

In addition to these long-term deployments, water quality probes were deployed at additional locations for the synoptic surveys. Datasondes were deployed at the Klamath River above Shasta River, Klamath River above Scott River, and Scott River at Mouth. Although the Klamath River above Shasta River site was coincident with the synoptic sample site, the Klamath River above Scott River was located approximately 0.5 miles upstream from the grab sample location for safety reasons. Similarly, the probe deployed in the Scott River was located above the highway 97 bridge to place it away from more heavily used areas.

2.5. Water Temperature Sample Site Descriptions

Water temperature was collected at four locations between Iron Gate Dam and Seiad Valley (Table 2-4). The Klamath River at Cottonwood Creek was coincident with the algae study site. Klamath River above Shasta River sampling was coincident with the synoptic grab sample site. Klamath River above Scott River was coincident with the Datasonde deployment site. Finally, temperature monitoring at Scott River was completed approximately one mile upstream from the mouth. The site was located approximately 1000 feet downstream of the Scott River Road bridge and was accessible via a public access road to the river. Water temperature loggers were deployed between 5 and 30 feet (depending on site conditions) from the bank in steel canisters attached to the shore with braided cable.

Table 2-4 Water temperature logger deployment locations

Sampling Location	Latitude	Longitude
Klamath River ab. Cottonwood Ck.	N41° 53.564’	W122° 32.124’
Ab. Shasta River	N41° 49.877’	W122° 35.606’
Klamath River ab. Scott River	N41° 46.892’	W123° 1.928’
Scott River nr. Mouth (RM 1)	N41° 45.944’	W123° 1.366’

2.6. Algae Sample Site Descriptions

Algae sampling sites were limited to two mainstem Klamath River locations: below Iron Gate Dam and above Cottonwood Creek (Table 2-5). The site below Iron Gate Dam was located on the left bank of the river adjacent to the fish hatchery and just upstream of the hatchery return. This location was across the river and downstream approximately 100 feet from the grab sampling site. The Cottonwood Creek site was coincident with the water temperature monitoring site. Additional site details are addressed under Special Studies.

Table 2-5 Algae study site locations

Sampling Location	Latitude	Longitude
Klamath River bel. Iron Gate Dam	N41° 55.791’	W122° 26.579’
Klamath River ab. Cottonwood Ck.	N41° 53.564’	W122° 32.124’

2.7. Trace Element Screening Sample Site Descriptions

Trace element sampling was completed at four sites in the study region (Table 2-6). All sites were coincident with semi-monthly grab sample locations with the exception of the Link river bridge. Collected from the Link River Bridge approximately 2 miles downstream from Link Dam. Sampling occurred by filling the churnsplitter directly from the river and all samples were then processed with a churnsplitter.

Table 2-6 Trace element grab sample locations

Sampling Location	Latitude	Longitude
Klamath River at Link River Bridge	TBD	TBD
Klamath Straits Drain (KSD) @ Hwy 97	N42° 4.846’	W121° 50.833’
Keno Bridge	N42° 7.627’	W121° 55.700’
Klamath River bel. Iron Gate Dam	N41° 55.865’	W122° 26.517’

Field data required some level of processing or review to ensure data were representative of actual field conditions. Beyond direct examination of field observations, processing typically included review of field notes, sampling methods and field protocols, and identifying the instrumentation employed and analytical methods applied. Because the sampling program utilized several methods to collect a wide variety of parameters on different time scales, several methods were employed. The final data sets presented herein have been reviewed and are considered final, unless otherwise noted.

3.1 Semi-monthly and Synoptic Grab Samples

Grab sample data have undergone data validation by USBR MP157 in accordance with the quality assurance program plan (see Appendices). For specific quality procedures for quality assurance of all analytical samples the reader is referred to USBR (2000). Although metals were collected via grab sampling, they are discussed separately.

Processing of the grab sample data was primarily limited to estimating parameter values below the reporting limit, quantifying the uncertainty associated with selected data, presenting summary statistics, and graphical representation. Incorporation of comprehensive quality assurance samples for field and laboratory assessment not only provided a greater level of confidence and legitimacy to a data set, but also provided a means of assigning uncertainty to the data. For scientific applications, high quality data is an obvious benefit, but the concomitant benefit of quantifying uncertainty in data is invaluable – especially in the Klamath River basin where a wide range of constituent concentrations may be encountered.

A primary issue with nearly all grab sampling programs is the limitations of analytical (i.e., laboratory) methods to detect small concentrations of certain constituents. The result is that some data at certain locations and/or times are presented as “less than” (<) a detection or reporting limit. This data was termed “censored.” Table 3-1 illustrates censored data for Klamath River at Miller Island in May 2000. Ammonia (NH_4^+), nitrite plus nitrate ($NO_2^- + NO_3^-$), and biochemical oxygen demand (BOD) data all include censored values (bold). These values were below the reporting limit. It is critical to note that the reporting limit for these methods varied from roughly 1 to 3 times the laboratory method detection limit, depending on the constituent. (The reporting limits and method detection limit statistics are maintained by the laboratory and are updated infrequently, e.g., annually.). That is, the laboratory could detect smaller quantities of a constituent, but not necessarily in a consistent fashion (e.g., consistent with internal laboratory QA). The reporting limit is commonly two to ten times greater than method detection limits to ensure reliable, repeatable laboratory results.

Table 3-1 Klamath River at Miller Island (censored data in bold)

Site	Date	Time	NH_4^+ (mg/l)	TKN (mg/l)	NO_3^- + NO_2^- (mg/l)	TP (mg/l)	PO_4^{3-} (mg/l)	BOD (mg/l)
KRMI	05/01/00	10:30	**<0.05**	0.9	**<0.05**	0.22	0.16	4.0
KRMI	05/09/00	14:36	0.29	0.8	**<0.05**	0.34	0.27	**<3.0**
KRMI	05/23/00	09:15	0.27	0.8	**<0.05**	0.28	0.28	4.0

Data was estimated for samples where the concentration was below the reporting limit (and potentially below the method detection limit as well) to facilitate computation of summary statistics. There are several methods for estimating data below the reporting (or detection) limit including simple methods such as setting all values below the reporting limit to (a) the reporting limit, (b) to zero, (c) to one half of the reporting limit. However, more rigorous methods are presented by Gilliom and Helsel (1986), including estimating censored data assuming that censored observations follow a zero to reporting limit lognormal distribution based on non-censored data. The process is straightforward:

1) Log-normal probability plots (a.k.a. exceedence plots) are constructed for a particular parameter based on the uncensored data.
2) A least squares regression is fit to the data.
3) Values below the reporting limit are calculated using the least squares regression for each plotting position.

For example, to construct the probability plot all values are ranked by magnitude and the plotting position determined by the general equation

$$q_i = \frac{i-a}{n+1-2a} \qquad (1)$$

where q_i is probability plotting position (exceedance probability), i is plotting position (rank), a is plotting position parameter, and n is number of samples. Several formulae based on Equation 1 are available, including Weibull, Median, Blom, Cunnane, and Hazen (Stedinger et al, 1993). A Weibull distribution (a = 0) was used for this project.

Table 3-2 illustrates the $NO_2^- + NO_3^-$ data for Klamath River at Miller Island for the 2000 season. The data have been ranked from low to high, three censored values exist, and plotting position based on Equation 1 is presented.

Table 3-2 Klamath River at Miller Island $NO_2^- + NO_3^-$ data by magnitude with computed plotting position

Rank	Date	Censored Data	Uncensored Data	Plotting Position, q_i
1	05/09/00	<0.05		0.07
2	05/23/00	<0.05		0.13
3	05/01/00	<0.05		0.20
4	10/17/00		0.10	0.27
5	10/31/00		0.13	0.33
6	08/22/00		0.18	0.40
7	06/20/00		0.19	0.47
8	09/26/00		0.26	0.53
9	11/14/20		0.42	0.60
10	09/12/00		0.70	0.67
11	06/06/00		1.69	0.73
12	07/11/00		1.79	0.80
13	07/25/00		2.05	0.87
14	08/08/00		2.30	0.93
n= 14, a = 0				

Figure 3-1 illustrates a log-normal plot with a least-squares regression line and equation for the uncensored data (solid symbols). This equation was used to estimate data values for the remaining three data points below the reporting limit of 0.05 mg/l (open symbols). If the equation returned a value above the reporting limit, the value was set at the reporting limit, as was the case for the Klamath River at Miller Island $NO_2^- + NO_3^-$ - the calculated value at the 0.20 plotting position (80 percent exceedence) was 0.06 mg/l. The calculated values at the 0.07 and 0.13 plotting positions were 0.03 mg/l and 0.04 mg/l, respectively. As noted in the figure, the least-squares regression relationship provided a good representation of the data. Correlation coefficients were typically greater than 0.9, with the lowest value about 0.85 for all data sets. Standard error of the estimate (i.e., regression coefficients) was not computed. Based on findings of Gilliom and Helsel (1986) and Helsel and Gilliom (1986) data were not estimated below the reporting limit when greater than 50% of the data were censored.

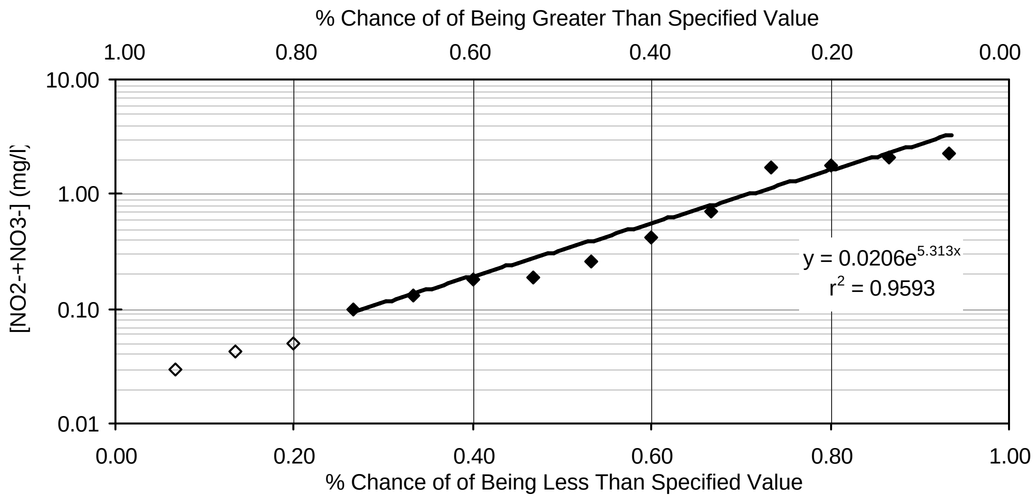


Figure 3-1 Log-normal probability plot, least-squares regression and estimated data for Klamath River at Miller Island $NO_2^- + NO_3^-$

Probability plots provide much more than a means to estimate data below the detection limit. By definition, they provide exceedance probabilities useful in many studies. For example, although based on a single year, Figure 3-1 illustrates that 50 percent of the time $NO_2^- + NO_3^-$ concentrations will exceed approximately 0.3 mg/l, and about 75 percent of the time concentrations will exceed 1.0 mg/l from mid-spring through mid-fall.

3.2 Other Data

To compliment the grab sampling program, water quality probes were used to collect physical measurements of water temperature, dissolved oxygen, electrical conductivity and/or specific conductance, pH, and redox during each sampling run. Turbidity data was also measured. Three turbidity samples were processed for each semi-monthly sampling location and collection, but turbidity was not measured during the synoptic surveys. The probe data, as well as the turbidity data have been reviewed and included in tabular form with the grab sample results. Due to equipment failure and logistical problems, some data were not collected at certain times and/or locations and are thus unavailable.

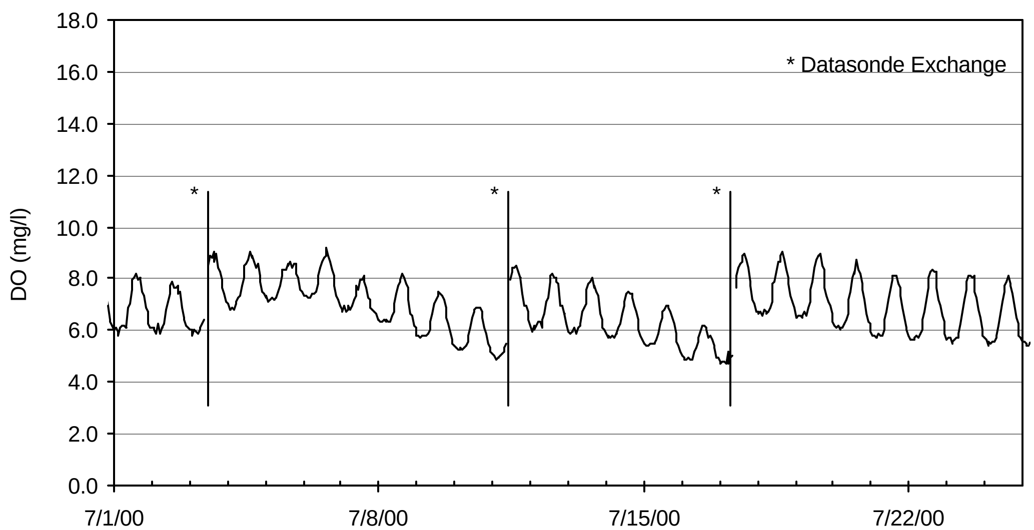
3.2.1 Datasonde

Datasonde parameters collected during the 2000 field season included hourly water temperature, dissolved oxygen, electrical conductivity and/or specific conductance, pH, and redox. Datasondes were exchanged at roughly weekly intervals. Because the probes were generally launched prior to field deployment and allowed to continue recording after retrieval, there was a considerable amount of post processing required.

Some fundamental challenges of collecting data with water quality probes includes probe malfunction, calibration problems/errors, data logging malfunction, and user error (e.g., setting incorrect start time). In addition, probes require a high level of maintenance to obtain reliable, useful data. A lack of regular maintenance, including proper care (calibration, replacing and/or using the proper dissolved oxygen membranes) are common problems in water quality monitoring with these instruments.

Finally, the water quality environment in which the probes were deployed played a critical role in data quality. Throughout much of the Klamath River basin these probes were deployed in enriched systems. The probes experienced water temperatures approaching 30°C (86°F), dissolved oxygen (DO) concentrations ranging from 0 mg/l to over 15 mg/l (with daily variations up to 10 mg/l), and pH levels approaching 10.

A significant problem encountered throughout much of the study area was biofouling of the DO membrane. Recorded DO concentrations typically began to show degradation within 24 to 96 hours. Figure 3-2 illustrates recorded hourly DO at in the Klamath River near Seiad Valley from June 1-25, 2000. Degradation in measured DO occurred immediately in some cases. It is clear this was not an accurate portrayal of system dynamics because each time the probe was exchanged there was a step increase of 2 mg/l to 3 mg/l. This problem was insignificant in the early to mid-spring periods and in the late fall, but during the late spring through early fall period much of the DO data was affected. At sites where DO was severely depressed (e.g. Miller Island), such problems were not usually apparent, probably because there was very little DO



present.

Figure 3-2 Recorded dissolved oxygen concentration, Klamath River at Seiad Valley USGS gage: June 1-25, 2000

In addition to concerns with dissolved oxygen, other parameters also experienced problems. Redox observations typically doubled in value during the one-week deployment periods. It is surmised that this problem was associated with primary production.

A separate limitation of the water quality probes is that individual probes may report different constituent concentrations when placed in the same body of water. Most likely the differences occur due to improper calibration, probe drift, probe malfunction, instrument mishandling, improper membrane, not letting a membrane mature, hardware, and/or age. Regardless of the cause, the result was that probe readings can differ well in excess of factory specifications. An example of this problem is illustrated in recorder pH in the Klamath River near Seiad Valley (Figure 3-3). To address these conditions all probes used in the WQ2000 sampling program were tested simultaneously and their results compared. Details and results of the test are included in the Data Appendix document.

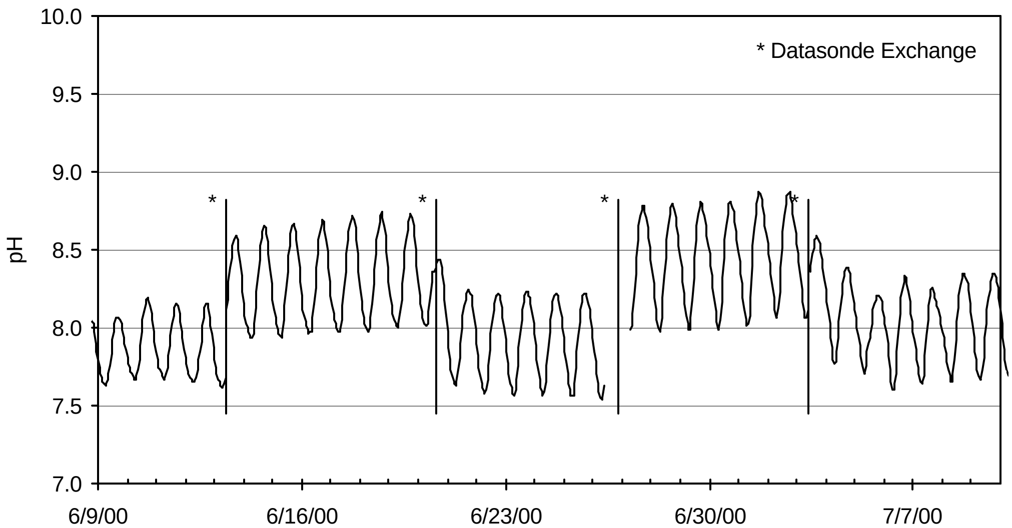


Figure 3-3 Recorded pH, Klamath River at Seiad Valley USGS gage: June 9-July 10, 2000

Although information exists to potentially correct, as well as assign uncertainty to the water quality probe data, no such measures were undertaken. The individual weeklong data sets were examined using field logs to determine precise time of deployment and retrieval and only periods of river deployment were retained. Further, the data were graphed and basic summary statistics (mean, maximum, and minimum values) determined as an evaluation measure. However, due to the large amount of data, post correction of the time series is left to the end user.

3.2.2 Water Temperature

Water temperature data was collected using Onset Corporation Stowaway® temperature loggers. The primary data quality control measure applied to these data was to carefully review and remove observations from the records that occurred prior to deployment and after retrieval. Further, a review was competed to ensure the loggers were not exposed to the atmosphere during deployment, thus recording air temperature instead of water temperature. (The accuracy of these devices is ±0.2°C (0.36°F) at 20°C. All devices were tested prior to field deployment.)

3.2.3 Algae

Algae data were collected over four week periods twice during the summer of 2000. These data did not require any special processing and are presented in discussed in the Special Studies section.

3.3 Program Data

All program data and explanations for data presentation are located in the Klamath River Water Quality 2000 Data Appendix. Table 4-1 lists the reference and title for all data include within the Data Appendix. Further details can be found in the Data Appendix table of contents.

Table 4-1 Data Appendix table of contents

Appendix	Title
A	Semi-Monthly data by sampling site
B	Semi-Monthly data by sampling date
C	Semi-Monthly data by sampling site: summary statistics
D	Semi-Monthly data: graphical representation by site
E	Semi-Monthly data: Probability plots by site
F	Synoptic Survey Data
G	Synoptic Survey Data: summary statistics
H	Synoptic Survey Data: graphical presentation by site
I	Synoptic Survey: DataSonde records
J	Datasonde Data
K	Water Temperature Data
L	Metals and Aquatic Life Criteria
M	Benthic Algae Data
N	Reservoir Water Quality Data: grab samples
O	Reservoir Water Quality Data: grab samples, graphical representation by site
P	Reservoir Profile Data
Q	Reservoir Thermistor Strings
R	River and Reservoir Flow Data
S	Reservoir Stage and Volume Data
T	Meteorological Data
U	DataSonde Population Testing

4. SPECIAL STUDIES

In addition to the baseline sampling program, three special studies were implemented. These included intensive synoptic surveys, algal growth studies, and trace elements screening.

4.1 Synoptic Survey

Previous water quality modeling studies of the Klamath River between Iron Gate Dam to Seiad Valley identified a need for additional data within this study reach to improve water quality characterization and provide supplementary data for modeling. One issue of interest was the sub-daily response of water quality in the river system. To achieve this goal several synoptic studies consisting of grab samples and water quality probe deployment were designed and implemented.

Six sampling locations were designated for intensive study over three day periods. The sites include

- Klamath River below Iron Gate Dam
- Klamath River above Shasta River
- Shasta River
- Klamath River above Scott River
- Scott River
- Klamath River at USGS Gage near Seiad Valley

Grab sampling occurred three times per day with the morning collection between 6:00 a.m. and 8:00 a.m.; mid-day collection between 10:30 a.m. and 1:00 p.m. and afternoon collection between 1:30 p.m. and 3:30 p.m. The morning, mid-day, and afternoon sampling “windows” were target periods. Some samples were not collected within these periods due to travel logistics and shipping schedules (the reader is referred to the Data Appendix where exact sampling times are reported). Datasondes were deployed during the initial sampling visit and retrieved at the end of the three day period. The synoptic surveys were completed June 5-7, August 7-9, and September 27-29, 2000. The September survey consisted only of water quality probes at the selected sites.

Grab samples included ammonia, nitrate+nitrite, total Kjeldahl nitrogen, total phosphorous, orthophosphate, organic nitrogen (dissolved), and organic phosphorous (dissolved). Water quality probes were used to collect water temperature, dissolved oxygen, pH and specific conductance on 30 minute and one-hour intervals. All data are included in the data appendix. Outlined below are details related to these synoptic surveys.

4.1.1 Synoptic Survey: June 5-7, 2000

The June synoptic survey started on June 5 and ran for three consecutive days. During the morning sampling session on the first day the Datasondes were deployed in the Klamath River above the Shasta and Scott Rivers. There was no Datasonde available for the Scott River until the afternoon of the first day. A YSI dissolved oxygen meter was used to take intermittent reading readings at this site during the morning and mid-day sampling sessions. The probe located at the Scott River did not have the protective canister identified in the Datasonde Protocol. All Datasondes were recovered during the afternoon (last) grab sampling effort on June 7. The Datasonde in the Klamath River above the Scott failed to record any data.

The study site experienced warm weather through much of the sampling period, with temperatures ranging from 5°C (41°F) to over 31°C (89°F). High clouds were evident each day (possibly originating from the approaching cold front). Still, days were mostly sunny and warm with the exception of Wednesday. Wednesday morning clouds were evident early in the day, while conditions remained mild. By late afternoon, a cold front had arrived and by evening scattered showers occurred in the study area.

4.1.2 Synoptic Survey: August 7-9, 2000

The August synoptic survey started on Monday, August 7 and ran for three consecutive days. During the morning sampling session on the first day the Datasondes were deployed in the Klamath River above the Shasta and Scott Rivers and in the Scott River. The Datasonde deployed in the Klamath River above the Scott River was on loan from the North Coast Regional Water Quality Control Board. This probe did not have the protective canister identified in the Datasonde Protocol. All Datasondes were recovered during the afternoon (last) grab sampling effort on August 9.

The study site experienced hot weather through much of the sampling period, with temperatures ranging from about 17°C (63°F) to over 36°C (97°F). Thunderstorm activity and associated showers occurred during the late afternoon and evening of each day. Cloud cover from this activity often lingered into the early morning hours. All days were clear by 9:00 a.m., except August 9, when cloud cover did not clear until approximately 11:30 a.m.

4.1.3 Synoptic Survey: September 27-29, 2000

Upon completion of the first two synoptic surveys it was determined that an additional full water quality survey was not required. During the September survey, no water quality grab samples were collected. However, water quality probes were deployed at the designated synoptic sites that were not covered under the Datasonde deployment program (specifically, Klamath River above the Shasta River, Klamath River above the Scott River, and Scott River at mouth.) The probes were left in place for one week to monitor temperature, dissolved oxygen, pH, and specific conductance.

The study site experienced weather conditions typical of late fall "Indian summer." Temperatures ranged from about 10°C (50°F) to over about 28°C (82°F). Days were warm with cool nights and few clouds.

4.2 Benthic Algae

Primary production in the Klamath River plays a critical role in water quality response, particularly in the spring, summer and fall months. In reservoirs primary producers consist of diverse phytoplankton assemblages. For example, Iron Gate Reservoir includes several species of diatoms (*Stephanodiscus, Synedra,* and *Melosira*); blue green or cyanobacteria (*Aphanizomenon* and *Oscillatoria*), as well as Cryptophyta (*Chrytomonas* and *Chroomonas*), and Chlorophyta (*Schroederia*) (EPA, 1978). Certainly some of these species wash from the reservoirs and lakes into the downstream river reaches. Further, impounded reaches may support considerable phytoplankton populations under certain hydrologic, climatic, and water quality conditions. However, in the free flowing river reaches these planktonic species fare poorly and the dominant forms include periphyton, other benthic algae and rooted aquatic plants.

To support modeling efforts in the reach between Iron Gate Dam and Seiad Valley, a benthic algae study was completed to estimate algal growth rates for water quality simulation. A review of available methods and extensive conversations with United States Geologic Survey staff (pers.

comm. S. Porter, K. Carpenter, T. Brown, L. Brown) led to a preliminary effort to deploy unglazed ceramic tiles on the riverbed. Such artificial substrates have a number of limitations including loss due to high flows, burying (sedimentation), grazing losses, and bias toward communities actively colonizing at the time of placement. However, they can be useful in estimating algal species growth rates over longer periods of time (Porter et al, 1993).

The preliminary artificial substrate consisted of six-inch square tiles attached to 8-inch by 16-inch cinder blocks with epoxy. The tiles were placed in the river on March 22, 2000 to "condition" and "inoculate" the tiles, and assess their efficacy in monitoring algal growth. The clay tiles were conditioned because the tile can exhibit a surface charge phenomenon, and this electrostatic charge can impede algal growth at the outset (S. Porter, pers. comm.). Although the tiles were not to be sampled until June, placing them in the stream several months ahead of time allowed for at least a precursory level of colonization (inoculation). The tiles were left submerged in the river from late March through August, i.e., they were not allowed to desiccate.

Initially, three locations for tile deployment were selected in the Klamath River: below Iron Gate Dam (RM 190), above Cottonwood Creek (RM 182), and above the Shasta River (RM 176). Four tiles (two cinder blocks) were placed at each location. Iron Gate Dam release during deployment was in excess of 3100 cfs precluding placement of tiles more than approximately 20 feet from shore at the Cottonwood Creek and Shasta River sites, only five feet at Iron Gate Dam. Water temperature was approximately 9°C (48°F), emergent shoreline vegetation (cattail, eel grass) was largely absent, and riparian vegetation was dormant. At the time of placement the majority of the bed was colonized by *Cladophora*.

On April 19, 2000 the tiles were examined. At Cottonwood Creek the tiles were completely bare due to heavy grazing by snails. Literally hundreds of snails were observed on the tiles. Grazing was so heavy that attempts to recover algae by scraping the tile with a razor blade yielded no appreciable substrate. In contrast, the tiles below Iron Gate Dam experienced luxuriant growth, with unidentified filamentous algae up to two inches in length. Further, there was no sign of grazing and no snails were observed. However, it was observed that the density of algae varied greatly among the four tiles, with one tile having almost no growth. Finally, it was evident that the Shasta River location had potentially different shading conditions – both topographic and riparian – than the other sites, and the tiles were removed and placed at the Iron Gate Dam and Cottonwood Creek sites. Two sampling periods, one in June and one in August, were selected for sampling. Floating periphyton samplers were added to the program to minimize grazing impacts. Discussion of each sampling effort and results are outlined below.

4.2.1 June 5 - June 30, 2000

Floating periphyton samplers were deployed on June 5 and attached to anchors set on the streambed. All ceramic tiles were removed from the river and vigorously scrubbed with a nylon brush to remove existing algae, then replaced in the river adjacent to the floating samplers. The sites were visited regularly over the first few days to assess deployment conditions. The sites were subsequently visited on June 14, 22, 26, and 29, 2000. It was apparent that floating strands of filamentous algae would catch on the anchor line and foul the samplers. The California Department of Fish and Game assisted in collecting randomly selected microscope slides for laboratory processing from floating samplers and completing the narrative description of conditions present on the ceramic tiles. New slides were placed in the sampler to replace those removed for processing in order to maintain similar flow conditions in and around the sampler throughout the sampling period – these new slides were not sampled. Single slides were placed in 125 ml bottles and shipped to laboratory on dry ice.

During the first weekly visit fouling of the floating samplers appeared to interfere with the samplers. A t-post was installed upstream of the individual samplers to catch the floating debris. This approach was largely successful at all sites.

Results of the June sampling period for dry weight and ash-free dry weight both Iron Gate Dam and Cottonwood Creek sites are presented in Figure 4-1 and Figure 4-2, respectively. Results indicate a steady increase in algal biomass during the sampling period with the exception of the last sample point at Iron Gate Dam, when algae actually died back. The reason for this condition is unknown. One possible explanation may be that the original colonizing algae were dependent on cooler water temperatures. Iron Gate Reservoir and Dam operations serve to moderate temperature to a large degree, resulting in nearly constant temperature over short periods (hours, days), but releases do exhibit seasonal warming during the summer months. As seasonal temperature warmed from about 17°C on June 5 to over 20°C on June 29 the original algae assemblage or a portion of the original alga assemblage may have suffered. Other possible explanations could be disease, parasitism, and changes in environmental conditions (other than temperature).

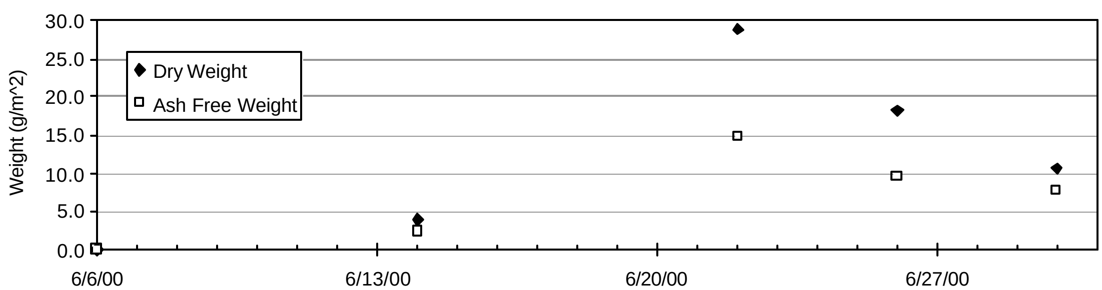


Figure 4-1 Iron Gate Dam dry weight and ash-free dry weight: June, 2000

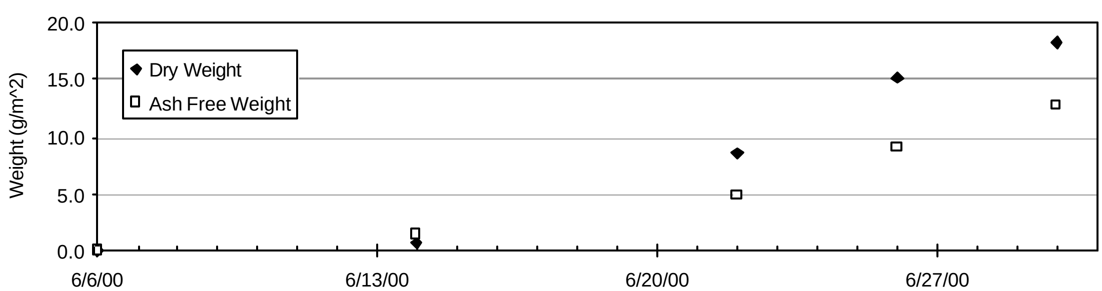


Figure 4-2 Klamath River above Cottonwood Creek dry weight and ash-free dry weight: June, 2000

4.2.2 August 8 - August 28, 2000

Floating periphyton samplers were deployed on August 8th attached to t-posts. As with the previous sampling effort, all ceramic tiles were removed from the river and vigorously scrubbed with a nylon brush to remove existing algae, then replaced in the river adjacent to the floating samplers. The sites were visited regularly over the first few days to assess deployment conditions. The sites were subsequently visited on August 16, 21, 23, and 28, 2000.

Results of the August sampling period for Ash-free dry weight and Chlorophyll a for both Iron Gate Dam and Cottonwood Creek sites are presented in Figure 4-3 and Figure 4-4, respectively. Results at Iron Gate Dam indicate somewhat similar conditions to the June period, except during this deployment no algae dieback was observed at any time during the period. Results for the Klamath River above Cottonwood Creek are markedly different. Compared with Figure 4-2, above, the growth rate is significantly smaller, and one could argue that, as exhibited by AFDW, that little growth was evident. These findings are discussed further under modeling studies.

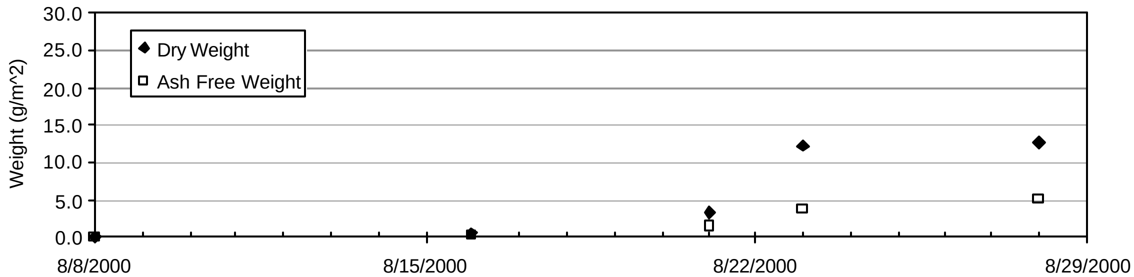


Figure 4-3 Iron Gate Dam dry weight and ash-free dry weight: August, 2000

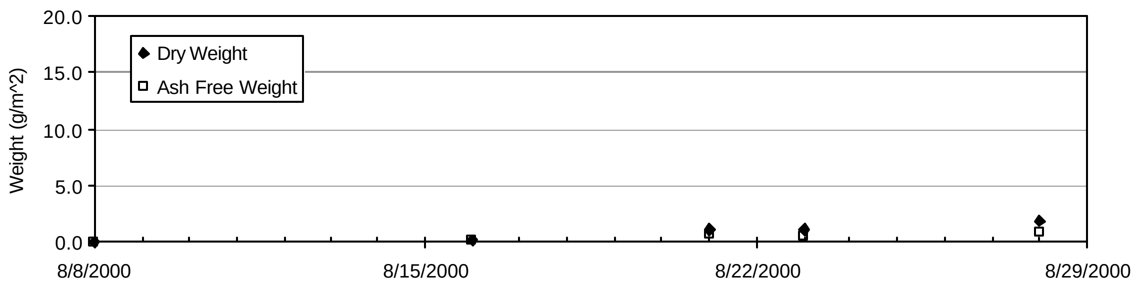


Figure 4-4 Klamath River above Cottonwood Creek dry weight and ash-free dry weight: August, 2000

4.2.3 Species Identification

Limited species identification was carried out during the sampling periods. Macroalgae identified in the study reach included widespread colonization of the riverbed by *Cladophora* and *Potamogeton* (*P. crispus and P. pectinatus)*. Other benthic algae identified included *Ceratophylum* and *Elodea*, two non-endemic species. Artificial substrate was collected from a floating periphyton sampler for algal identification during August. The periphyton community was dominated by pennate diatoms (*Cocconeis, Navicula, Nitzschia, Gomphonema*, and *Fragilaria*). The identified species tended to be on the higher side of trophic status, i.e., they suggest an elevated nutrient content in the water (J. Sweet, pers. comm.).

4.3 Trace Elements and Metals

Trace elements and trace metals were screened at four locations in the basin during the 2000 field season: Link Dam, Klamath Straits Drain at Highway 97, Keno, and below Iron Gate Dam. Samples were collected on May 23, June 20, July 25, and September 26. The fifteen elements included in the screening samples are provided in Table 4-1.

Table 4-1 Trace element screening suite constituents

Aluminum	Antimony	Arsenic
Cadmium	Chromium	Copper
Iron	Lead	Magnesium
Mercury	Nickel	Selenium
Silver	Thallium	Zinc

All of the trace elements were inorganic compounds consisting of metals and nonmetals. Where applicable, freshwater aquatic life criteria were tabulated for each of the constituents. Freshwater aquatic life criteria for certain metals is a function of hardness, in which cases for the appropriate criteria the reader is referred to CEPA, (1998), for specific calculation procedures. Trace element sampling field data are included in the data appendix.

Aluminum, lead, and mercury exceeded freshwater aquatic life criteria during the program. During the first two sampling efforts aluminum exceeded aquatic life limits at all locations. For the latter two sampling dates aluminum was elevated only at Link Dam and in the Klamath Straits Drain. Lead levels were elevated in two samples, in the Klamath River below Iron Gate Dam (5/23/00) and the Klamath River at Keno (6/20/00). There were two instances when the aquatic life criteria were below the reporting limit for lead: Klamath River at Link Dam (5/23/00 and 7/25/00). However, no conclusive evidence can be drawn from these samples. Mercury was elevated for all sampling sites at least once during the 2000 monitoring program; however, Keno experienced levels in excess of the aquatic life criteria throughout the field season. In addition, for silver the aquatic life criteria were below the reporting limit for the entire season at Link Dam.

Concern over these metals varies. Aluminum can be a source of concern in drinking water for both health and human welfare. Aluminum in the form of alum is commonly used as a coagulant in water treatment, and can lead to discoloration in drinking water.

Lead is highly toxic and considered a probable carcinogen. Lead in surface waters can originate from natural sources, certain types of manufacturing (e.g., batteries), and from historic uses including lead paint and leaded gasoline. It has no known beneficial or nutritional effects and tends to accumulate in tissues of man and other animals.

Mercury is widely found in surface waters both naturally and as a byproduct of mining, manufacturing, pesticide production and application, and many other industries. A primary concern with mercury, beyond its well documented toxic effects, is bioaccumulation in the food chain. Both drinking water and aquatic life criteria exist for mercury.

Silver is a nonessential, non-beneficial element for humans, but is systemically toxic to aquatic life. Bioaccumulation, although apparently harmless in humans (at levels below drinking water standards), is a concern with fish life.

5. MODELING: ASSESSMENT AND APPLICATIONS

5.1 *Model Assessment*

One component of the project was updating, as necessary, the existing water quality model for the Klamath River mainstem between Iron Gate Reservoir and Seiad Valley. This included an investigation for improving representation of benthic algae in the model as well as incorporating year 2000 data in model calibration and validation. During the benthic algae monitoring study it became apparent that the Klamath River benthic community was not only extremely complex, but also poorly understood. The sampling effort provided the first concrete values on growth rates, and the dynamic processes that were observed in the system. Most notable were grazing by mollusks and invertebrates and the apparent shift of algal species below Iron Gate Dam as the river temperature changed. Further, respiration rate, another model parameter was not measured.

To further evaluate the options for representing benthic algae in simulation models a literature review was completed (see attached appendix). The findings identify important parameters in modeling benthic algae, associated biomass, dissolved oxygen and nutrient effects, and the overall importance of benthic communities. Fundamentally, rivers are different environments than lakes, wherein phytoplankton (free floating) algae typically dominate. The relatively fast moving water of river systems with short residence times prove a challenge to modelers aiming to represent these processes. Selected water quality models include logic to represent benthic algae; however, all struggle to characterize the diversity of benthic communities and their complexity and dynamics.

The current model, RMA-11, presumes that algae grow in accordance with a growth rate, respiration (and mortality) rate, and are limited by light and nutrients. Nutrient limitation is based on inorganic nitrogen and phosphorous forms. This fairly simple formulation incorporates only a single "bulk" community (represented by one set of parameters, i.e., it does not look at individual species) and does not directly account for losses by grazing, scour, senescence and sloughing, etc. Further, the selected initial conditions can affect simulated algal biomass at future time steps. Nonetheless, the model has provided considerable insight into the potential dynamics of primary production on water quality conditions in the Klamath River between Iron Gate Dam and Seiad Valley.

There are models available that provide a wider range of input parameters to represent the benthic community and its response on water quality. However, these models often require a large amount of data, or include simplifications of other processes that make them infeasible for most practical applications. Gathering information on the benthic community at a sufficient number of locations over a long period (e.g., spring through fall) would be required.

One available methodology may provide improved results with modest data collection costs, and at a minimum would provide additional data to the existing formulation. The general model representations follow a similar vein to that presented in RMA-11, that is the representation of a bulk community, but in this methodology algal biomass is calibrated to dissolved oxygen concentrations under steady-state conditions. Using a simulation model algal biomass is estimated consistent with dissolved oxygen observations and algal photosynthesis. Respiration rates are calculated based on the estimated algal mass accounting for stream re-aeration. Some models accommodate grazing and sloughing as well. By calibrating to dissolved oxygen the model aggregates all benthic processes into a "bulk" community. The limitation of the methodology is that it is most readily adaptable to steady-state conditions, while the conditions of interest in many cases are highly dynamic. Nonetheless, with systematic data collection over a broad reach of river, it is plausible that sufficient data could be gathered to represent a dynamic system response in space and time. Any such water quality study should include a corresponding ecological component to characterize the flora and fauna of the benthic community.

The model was applied under various conditions with the existing logic. The findings illustrate a system that is highly dynamic in space and time – results that are consistent with information from the field program. Based on these simulations and the results from the field monitoring program, it was determined that incorporating additional logic into the model without the appropriate data would be imprudent at this time. Although dissolved oxygen probes were in place during the 2000 field season, there are insufficient data to address the highly spatial variability of algal growth in the system. Further, additional fieldwork is necessary to further quantify photosynthesis and respiration (e.g., completion of light an dark bottle tests in tandem with water quality probes), sloughing studies, and grazing impacts. Upon completion of this data a complete update of the model, including calibration should be undertaken. Because model applications (see below) were predominately limited to water temperature response, water quality calibration was not revisited at this time (the model is already calibrated for temperature). Recommendations for these studies can be found in the conclusion of the report.

5.2 Model Application

The models and model output were used for various studies during the project period. The principal studies included examining the temperature impact of flow changes in the Klamath River below Iron Gate Dam during summer months. Two studies were completed; the first examined a specific flow change during the late summer and early fall months (August and September), while the second looked at a broader range of flows and cumulative effects over the June through September period.

5.2.1 Late Summer and Early Fall Flow Change: Iron Gate Dam to Seiad Valley

Varying the flow rate in the river can directly influence water temperature through increased transit time, varied depth and width, and altering the impact of tributary contributions. Model results illustrate that daily maximum temperatures are greater at a flow rate of 1030 cfs than at 1330 cfs for all days of the month – up to 1°C (1.8°F) greater at Seiad Valley. Daily minimum temperatures at Seiad Valley are lower at a flow rate of 1030 cfs than at 1330 cfs for all days of the month – up to 0.8°C (1.4°F) lower. The lower flow rate has a longer transit time – on the order of 6 to 8 hours longer between Iron Gate Dam and Seiad Valley. With shorter days and longer nights, the smaller thermal mass and depth associated with the 1030 cfs flow rate allows the river to heat and cool at a more rapid rate, leading to greater diurnal temperature swings in the river (~1.3°C / 2.3°F). Daily mean data tend to mask these conditions, thus hourly simulations were implemented. Flow changes (i.e., withdrawal rate) have the potential to affect the thermal structure of Iron Gate Reservoir as well.

It is apparent that reduced flows can lead to increases in mean daily water temperatures. However, short-term meteorological conditions play a significant role. Clear sky conditions can result in increased daily mean temperatures on the order of a few tenths of a degree Celsius between Iron Gate Dam and Seiad Valley for a flow change from 1330 cfs to 1030 cfs. However, when conditions cool (e.g., cold front), such as can occur during September, the lower flow scenario exhibits cooler water temperatures. The lower flow rate leads to extended exposure to cool conditions, and the smaller thermal mass cools more quickly.

5.2.2 Impact of Normal, Dry, and Critically Dry Hydrological conditions on Water Temperature: June – September

Temperature dynamics in the Klamath River below Iron Gate Dam are affected by upstream reservoirs, local meteorological conditions, regulation of releases to the Klamath River, quantity of release to the Klamath River and tributary contributions. Some principal findings include:

- Under drought conditions tributary contributions are typically small.
- Under typical summer time flows, re-regulation produces predictable "nodes" of minimum temperature variation separated by a one-day travel time in the river (at mean velocity). This phenomenon, apparent in sub-daily data and simulations, are critical in interpreting sub-daily water temperature information.
- Seasonal changes are apparent in the system as well as short term climatic meteorological conditions.
- Iron Gate Reservoir (and possibly Copco Reservoir) affect the thermal regime of the downstream river in three principle ways (under current operating conditions):
    - In mid-to late spring Iron Gate Dam releases are often slightly below equilibrium temperature, maintaining a slight cool water "benefit" for releases to the Klamath River.
    - In summer, there is minimal cool water benefit to the Iron Gate release (with respect to anadromous fishes). The release is only marginally below equilibrium temperature; however, the release does moderate the daily maximum and minimum temperature.
    - In fall, for short periods, the Iron Gate release can be warmer than equilibrium temperature. Under such conditions, the release is a heat source to the river. This condition is probably short lived.

Dissolved oxygen (DO) dynamics in the Klamath River below Iron Gate Dam were also simulated. The response of DO in the river downstream of Iron Gate Dam is a complex function of flow, release water quality, and primary production. A few notable findings suggest that:

- Simulated mean daily dissolved oxygen (as depicted in longitudinal profiles) is fairly constant throughout most of the summer throughout the river reach. However, in the fall, DO releases from Iron Gate dam begin to decrease to levels well below saturation.
- Further examination of the daily mean DO profiles illustrates that there is potentially appreciable primary production immediately below Iron Gate Dam, shown by a slightly increased daily mean DO.
- Examination of the simulated time series suggests that seasonally (and spatially) primary production directly and appreciably impacts sub-daily dissolved oxygen levels.
- The various flow regimes had a modest impact on daily mean DO concentration. The lower flows did produce a slightly higher mean daily DO, possibly due to increased aeration at shallower depths. Sub-daily data were more highly variable between alternatives, but these data have not been critically assessed at this time to provide an explanation for this response.

Simulated dissolved oxygen results have not been used in any quantitative manner. However, several of the above results are supported by field data.

Additional work under this task included review of various documents submitted to or prepared by USBR.

5.2.3 Algae Simulations

As noted above in the section on the benthic algae special studies, growth rates at the Cottonwood Creek site decreased dramatically during the August 2000 sampling period when compared to June 2000 (compare Figure 4-2 and Figure 4-4). These findings prompted a review of previous simulations of benthic algae in the Klamath River below Iron Gate Dam. Deas (2000) presented results from a simulation of longitudinal benthic algae biomass, reproduced below.

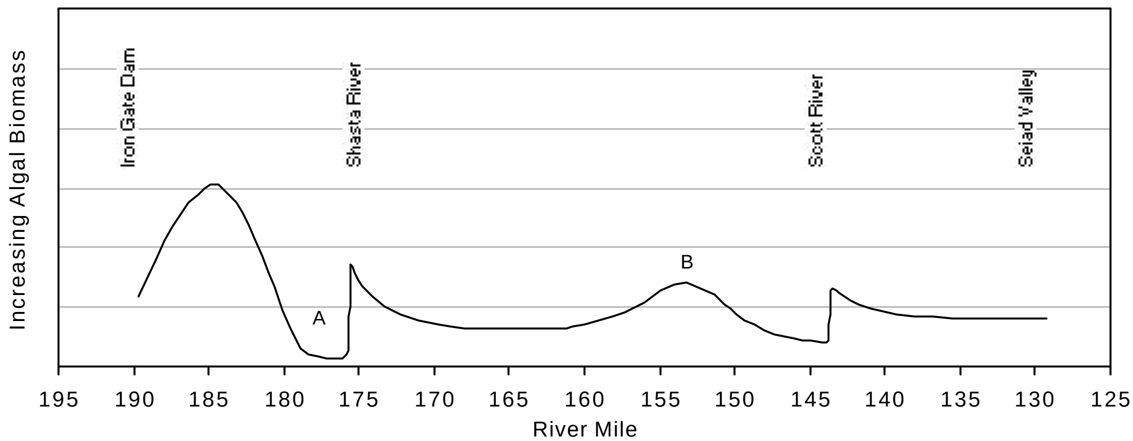


Figure 5-1 Hypothetical longitudinal profile of mean daily algal biomass in midsummer (from Deas, 2000)

The vertical axis in Figure 5-1 represents relative mean daily algal biomass (only a relative scale is presented because lack of field data precluded calibration of the model for attached algae), and the horizontal axis represents river mile with downstream progressing from left to right: Iron Gate Dam to Seiad Valley.

This simulation suggested a marked peak in algal biomass in the vicinity of RM 185 due to readily available nutrients from Iron Gate Reservoir releases. Further, assuming reservoir releases supply a relatively constant source of nutrients to the river, by mid-summer, algal biomass in the immediate downstream reach would approach equilibrium with respect to available nutrients. That is, biomass could potentially increase up to the point of effectively capturing the bulk of the nutrients. Thus, immediately downstream of this peak is a depression in algal biomass due to lack of available nutrients, labeled point A in Figure 5-1.

The original presentation of Figure 5-1 represented a hypothetical response using data from the month of June. Additional simulations were completed for the month of August to determine if the model would possibly capture a seasonal component to growth rate at Cottonwood Creek. Figure 5.2 presents relative algal biomass derived from model simulations for the months of June and August for the 15 miles of the Klamath River below Iron Gate Dam. Although this work is preliminary, these simulation results roughly correspond to field growth rate data from June and August. That is, in June the algal distribution is broad and extends beyond Cottonwood Creek, located at approximately RM 182.However, in August the distribution does not extend as far downstream. The results show a decrease in algal biomass through time, suggesting a reduction in standing crop. Review of Figure 4.4 wherein field data illustrate that growth rate at the Klamath River site near Cottonwood Creek is negligible, are consistent with such a condition.

At this time the results are suggestive, but form only a working hypothesis. Additional field work and modeling are required to further characterize the spatial and temporal algal dynamics below Iron Gate Dam, and to determine their impact on nutrient uptake, dissolved oxygen concentration, and unionized ammonia fractions, as well as the role of upstream reservoir water quality and operations. A literature review of mathematical modeling of benthic algae in general purpose water quality models was completed within this project to identify potential future approaches to simulating algae in the riverine system. Complete description of the logic and previous model applications are presented in Deas and Orlob (1999).

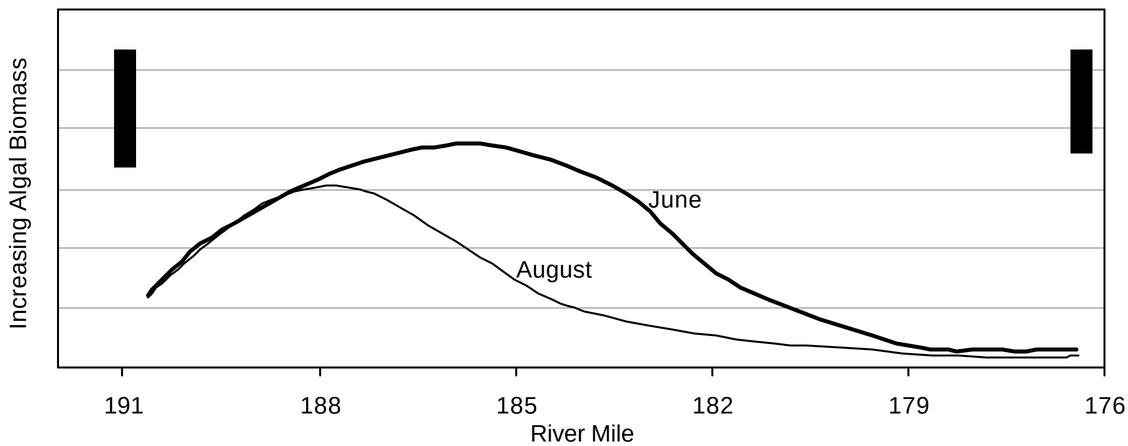


Figure 5-2 Hypothetical longitudinal profile of mean daily algal biomass in June and August

6. CONCLUSIONS AND RECOMMENDATIONS

The project objective to implement a basin wide program to collect baseline data was achieved. Through the semimonthly grab sampling program, deployment of water quality probes, and deployment of remote logging thermistors (loggers). Sampling was completed inn river reaches as well as within mainstem reservoirs. Additional information was collected through special studies, including algae studies, trace elements sampling, and intensive synoptic water quality surveys. This report presents the data form these programs, the techniques used to process the data, as well as supporting documentation on sampling protocols, quality assurances procedures, and appropriate documentation. Although this report by and large focuses primarily on field data, where analysis was completed or information obtained, attempts were made to document the information and findings.

Several findings and recommendation were identified during the project period and subsequent write-up. These are outlined below without regard to order of importance.

- Implementation of a quality assurance project plan and standard operating procedures (SOP) for field sampling provided consistent monitoring methods and allowed multiple agencies to sample in a consistent manner throughout the basin.
  Recommendation: USBR should maintain a QAPP and SOP for field sampling and seek to extend the application of uniform sampling procedures throughout the basin through sharing of the QAPP and SOP developed jointly by MP-157 and the Klamath Area Office staff.

- Implementation of external quality assurance samples (duplicates, spikes, blanks, and rinseate blanks) provided significantly improved confidence in the laboratory data.
  Recommendation: Although there is a cost associated with external quality assurance both in increased field supplies, additional laboratory samples, and in-house staff time to process the results, these quality assurance samples should be continued because the result is a high quality data set with uncertainty explicitly quantified.

- Monitoring with DataSondes illustrated that long-term collection of physical parameters is possible, albeit with certain limitations. Dissolved oxygen probes suffered from biofouling in a matter of days at many locations within the river. Additionally, ORP probes showed signs of drift during the week long deployments. The frequency of deploying and retrieving the water quality probes is problematic at a basin-wide scale. Limited resources (personnel) and shipping/transportation schedules restrict the deployments period to roughly a week. Finally, it was apparent that there was variation among the individual instruments when measuring pH, and dissolved oxygen.
  Recommendations:
  - Maintain the DataSonde deployment in selected locations.
  - Maintain Datasonde calibration and maintenance procedures to ensure probes are functioning properly and quantify uncertainty associated with individual sensors.
  - Complete pilot studies to determine the time/cost saving associated wherein field staff visit the sites more frequently (e.g., every 3 to 4 days) to clean the dissolved oxygen membrane and reduce download frequency to two weeks. Certain locations require a boat and increasing site visit frequency may be infeasible.
  - consider a pilot study to determine if completing Winkler titrations may assist in correcting dissolved oxygen data that have been affected by biofouling.
  - Testing the instruments in a single body of water prior to and at the end of each field season can quantify variation among probes. With regard to DataSonde

testing, it is recommended that a more rigorous statistical analysis be completed on the results.

- Coordination among multiple agencies can greatly improve the understanding of water quality conditions and response in large basins such as the Klamath River. Reclamation worked with PacifiCorp, the United States Forest Service, and the Yurok Tribe during the 2000 sampling season. In early 2001, and attempt was made to coordinate monitoring within the basin between Link Dam and the Pacific Ocean, including all major tributaries (Shasta, Scott, and Salmon Rivers). The objective of coordination was to identify consistent sampling locations and times, reduce redundant monitoring, identify available resources, introduce a minimum level of quality assurance and standard operating procedures, and share information. Attendance during the April 2001 coordination meeting held at US Fish and Wildlife Service was attended by over 40 people representing nearly every federal, state, tribal, and watershed group in the basin. Nonetheless, without funding the volunteer effort failed to successfully meet the objectives outlined above. <u>Recommendation</u>: Reclamation should seek to pursue coordination when opportunities arise. To some degree this has been done: Reclamation has shared the QAPP and SOP developed during the 2000 monitoring effort with any interested party in the basin. To the extent feasible, the Reclamation should work with other agencies to identify the potential for a basin-wide water quality coordinator position (not within the US Bureau of Reclamation) to encourage basin-wide coordination of monitoring efforts. Such a position, funded by all participants in the basin, would provide a critical role in ensuring that spatial and temporal water quality sampling be completed in a logical and appropriate fashion, that data quality assurance and sampling procedures be standardized, and that well defined methods for data dissemination are adopted. The result would lead to basin-wide water quality data that would be readily comparable across space and time versus the current efforts that are typically redundant, sample different parameters, include variable sampling times and locations, and utilize different analytical or measurement methods.

- All attempts were made to identify sites that were representative of mainstem conditions for the 2000 field sampling program. However, conditions at sampling sites may vary through time and under different hydrologic, meteorological, and water quality conditions.
  <u>Recommendation</u>: Continue to observe conditions at sampling sites and to carry out small scale studies, as resources allow, characterizing spatial (e.g., lateral and vertical) and temporal variations (e.g., seasonal and/or operational) at existing and proposed sampling sites. Document findings to support sampling methods and to assist in data interpretation.

- The benthic algae survey provided appreciable new information about the benthic flora and fauna. This information was not formally discussed herein primarily because it was much more complex than could be accommodated by the study plan. A brief review of the narrative descriptions of the conditions of the periphyton samplers and the unglazed ceramic tiles suggests that more detailed studies be completed to characterize these important processes.
  <u>Recommendation</u>: Because the primary impetus behind the 2000 field sampling program was to address anadromous fisheries downstream of Iron Gate Dam, and because the benthic flora and fauna play an integral role in the lifecycle of anadromous fisheries, it is recommended that additional work be completed to characterize the benthic community. The spatial and temporal variability of this community no doubt plays a vital role in

water quality throughout the system. A comprehensive study defining algal species present, estimates of biomass (e.g., through direct measurement, light and dark bottle test, or other means), identification of mollusks and invertebrate assemblages that graze on algae, and additional growth rate studies should be carried out over multiple field seasons to define the spatial and temporal variability of algae and its potential role in water quality. Reservoir operations, water quality, as well as the fate of phytoplankton (that is washed out of mainstem reservoirs) on downstream river reaches should be included.

- It is not uncommon for water quality monitoring programs to be funded, designed, and implemented, only to find that the field data is not processed and presented in a formal report.
  Recommendation: Data processing and reporting should be an integral part of any sampling program. Data dissemination procedures should be identified early in the sampling program design such that information can be available to interested parties.

- The model simulations provided insight into potential benthic algae dynamics; however, insufficient data are available to completely characterize the water quality response of the various components potentially affecting water quality (e.g., macroinvertebrate or mollusk grazing on benthic algae).
  Recommendation: continue to explore model formulations and approaches to more effectively characterize water quality response within critical reaches of the Klamath River system. This may include specific field studies designing to acquire critical information necessary to characterize physical, chemical, and biological processes. Temporal and spatial characteristics make this a challenging task.

- Field data indicate that mainstem reservoirs experience oxygen concentrations that deviate from saturation. Keno Reservoir, Copco Reservoir, and Iron Gate Reservoir all experience anoxic persistent conditions, which may lead to sediment nutrient release and thus internal nutrient cycling.
  Recommendation: to determine the potential for reduced conditions, oxidation-reduction potential (ORP) should be collected in all mainstem reservoirs when physical profiles are collected with water quality probes (e.g., DataSonde).

- Metals data were collected and are presented herein; however, as a stand alone data set there usefulness is limited.
  Recommendation: Review year 2000 field data in light of other sources of information concerning metals in the Klamath Basin and Klamath Project area.

- Adaptive management is a critical part of aquatic resource management. Although there are many definitions of adaptive management, a pragmatic approach consists of two steps: 1) conduct experiments to increase the knowledge of the system, and 2) plan to change based on the findings of first step.
  Recommendation: Identify components of the water quality monitoring program, possibly augmented by data or computer simulation models, to assist in adaptive management of water resources in the Klamath Basin.

7. REFERENCES AND ADDITIONAL RESOURCES

7.1 References

American Public Health Assc., American Water Works Assc., and Water Environment Federation (APHA). (1995) *Standard Methods for the examination of water and wastewater*, 19th Ed. Editors. A.E. Eaton, L.S. Clesceri, and A.E. Greenberg. Washington D.C.

Bowie, G.L. W.B. Mills, D.B. Porcella, C.L. Campbell, J.R. Pagenkopf, G.L. Rupp, K.M. Johnson, P.W. Chan, and S.A. Gherini. (1985). *Rates, constants and kinetics formulations in surface water quality modeling*, 2nd Ed. EPA/600/3-87/700. U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, GA. May.

California Environmental Protection Agency. (1998) *A Compilation of Water Quality Goals*. Regional Water Quality Control Board, Central Valley Region. March.

Capel, P.D., R.J. Gilliom, and S.J. Larson (1996) *Interpretation of data on low level concentrations of pesticides in water*. October 1, 1999. URL: http://ca.water.usgs.gov/pnsp/rep/interpret/

Chapra, S.C. (1997). *Surface Water-Quality Modeling*. McGraw-Hill. New York. 843 pp.

Colt, J., S. Mitchell, G. Tchobanoglous, and A. Knight. (1979). *The use and potential for aquatic species for wastewater treatment: Appendix B, the environmental requirements of fish*. Publication No. 65, California State Water Resources Control Board, Sacramento, CA.

Gilliom, R.J. and D.R. Helsel. (1986) Estimation of distribution parameters for censored trace level water quality data, 1, estimation techniques. *Water Resources Research*. 22(2), pp 135-146.

Helsel, D.R.. and R.J. Gilliom (1986) Estimation of distribution parameters for censored trace level water quality data, 2, verification and applications. *Water Resources Research*. 22(2), pp 147-155.

Horne, A. J., and Goldman, C. R. (1994). *Limnology*. 2nd ed. McGraw-Hill, New York. 576 pp.

Oblinger Childress, C.J., W.T. Foreman, B.F. Conner, and T.J. Maloney. (1999) *New reporting procedures based on long-term method detection levels and some considerations for interpretations of water quality data provided by the U.S. Geological Survey National Water Quality Laboratory.* U.S. Geological Survey Open File Report 99-193, 19 p.

Porter, S. D., T.F. Cuffney, M.E. Gurtz, and M.R. Meador. (1993) *Methods for collecting algal samples as part of the National Water-Quality Assessment Program*. U.S. Geological Survey Open File Report 94-455, 42 p.

Sawyer, C.N., P.L. McCarty, and G.F. Parkin. (1994) *Chemistry for Environmental Engineering*, 4th Ed. McGraw-Hill, Inc. New York.

Stedinger, J.R., R.M. Vogel, and E. Foufoula-Georgiou. 1993. Frequency analysis of extreme events (Chapter 18). Handbook of Hydrology. Ed. D.R. Maidment. McGraw-Hill, Inc. New York.

Stumm, W., and Morgan, J. J. (1962). “Stream pollution by algal nutrients,” in *Transactions, Twelfth Annual Conference of Sanitary Engineers*, Univ. Kansas.

Stumm, W., and Morgan, J. J. (1981). *Aquatic Chemistry; An Introduction Emphasizing Chemical Equilibria in Natural Waters.* Wiley-Interscience, New York.

Tchobanoglous, G and E.D. Schroeder (1985) *Water Quality*. Addison-Wesley Publishing Co., Inc. Menlo Park, CA.

United States Environmental Protection Agency (EPA). (1976) *Quality Criteria for Water (Red Book)*. Washington D.C. July.

United States Environmental Protection Agency (USEPA). (1997). *Technical Guidance Manual for Developing Total Maximum Daily Loads; Book 2: Streams and Rivers, Part 1: Biochemical Oxygen Demand/Dissolved Oxygen and Nutrients/Eutrophication*. EPA-823-B-97-002. March.

United States Environmental Protection Agency (USEPA). (1984). *Ambient Water Quality Criteria for Ammonia*. EPA 440/5-85-001. January.

Wagner, R.J., H.C. Mattraw, G.F. Ritz, and B.A. Smith. (2000). *Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation and Reporting*. U.S. Geologic Survey. Water-Resources Investigations report 00-4252.

7.2 Personal Communications

Stephan Porter, United States Geological Survey (Denver)
Jim Sweet, Aquatic Analysts
K. Carpenter, United States Geological Survey
T. Brown, United States Geological Survey
L. Brown, United States Geological Survey

7.3 Additional Resources

Several sources of water quality data and related discussions are available for the project area. These include, but are not limited to the references listed below. In certain cases, field and laboratory protocols are not included in the documentation and care should be used in interpretation.

7.3.1 Text Sources

California Department of Water Resources. 1986. *Shasta/Klamath Rivers Water Quality Study.* Northern District. February.

California Department of Water Resources. 1987. *Klamath Rivers Water Quality Study: Hamburg to Orleans*. Northern District. March.

California Department of Water Resources (DWR). 1991. *Shasta Valley Water Quality Literature Review*. Prepared by D. Bogener, Northern District, memorandum.

Deas, M.L. 2000. Application of Numerical Water Quality Models in Ecological Assessment. Ph.D. Dissertation. UC Davis 2000. March.

Dong, A.E., K.W. Beatty, R.C. Averett. 1974. *Limnological Study of Lake Shastina, Siskiyou County, California*. United States Geological Survey, Water Resources Investigation 19-74.

MacCoy, E.D. 1994. *Physical, Chemical and Biological Data for Detailed Study of Irrigation and Drainage in the Klamath Basin, California and Oregon, 1990-92*. US Geological Survey Open File Report 93-497. In cooperation with US Fish and Wildlife Service, U.S. Bureau of Reclamation and U.S. Bureau of Indian Affairs

North Coast Regional Water Quality Control Board (NCRWQCB) 1993. *Investigations of Water Quality in the Shasta River, Siskiyou County*. Prepared by B. Gwynne. Santa Rosa, CA. September.

North Coast Regional Water Quality Control Board (NCRWQCB) 1997. Water Quality Sampling, Clean Water Act 104(b) grant project data set. Draft data set.

North Coast Regional Water Quality Control Board (NCRWQCB). 1996. *Water Quality Control Plan for the North Coast Region*. North Coast Region, Santa Rosa, CA.

Smith, R.S. 1995. *A Water Resources Evaluation for Shasta Valley, Siskiyou County, California*. Masters' Thesis, California State University, Chico.

US Environmental Protection Agency. 1978. *National Eutrophication Survey – Report on Iron Gate Reservoir, Siskiyou County, California, EPA Region IX*. Working Paper No. 749. Produced in cooperation with the California State Water Resources Control Board and the California National Guard. June.

Wood, R. and D.W. Rogers. 1991. *Shasta River Fisheries Water Quality Project*. Prepared by Ouzal Enterprises for the Shasta Resources Conservation District.

7.3.2 Electronic Sources

EPA STORET

Various CD ROMS available for purchase: e.g., Earthinfo, Hydrodata, etc.

APPENDICES

APPENDIX A: REVIEW OF EXISTING DATA

The review of the existing water quality data for the 1998 and 1999 field program was instrumental in design and implementation of the to 2000 field program. The initiation of a large water quality monitoring program is a substantial task, and the efforts of USBR and USGS-BRD provided a solid foundation upon which to build. Four fundamental findings resulted from the review of the 1998 and 1999 data:

- A clear need existed for formal lab oversight and external quality assurance, as well as standard operating procedures for field sampling (grab samples and water quality probes (Datasondes))
- That sufficient data had been collected to allow a reduction in sampling parameters to accommodate the increased costs of QA processes and procedures.
- A need to expand the metals sampling from a limited set (four metals of concern) to a screening of fifteen trace elements.
- That results for certain constituents were erroneous or unreliable.

Review of the data demonstrated that confidence in the data varied widely. Because a formal QA program was not in place the data set should be used with caution. In light of the findings of the 2000 field program, much of the data is probably useful, but lacking QA (1998 and 1999 data) the 2000 data are not readily comparable. In addition, after review of field data and laboratory procedures certain data were found to be un-useable and it is recommended that they be discarded. These data include all metals data from 1998 and Cadmium from 1999. Two pieces of correspondence related to this topic are included below: (1) Memo from M. Deas of Watercourse Engineering, Inc. to L. Dugan of the U.S. Bureau of Reclamation, (2) Memo from MP-157 (U.B. Bureau of Reclamation, formerly MP 470) concerning laboratory performance.

Date: 4-7-00

TO: Larry Dugan

FR: Mike Deas

RE: Laboratory Selection

The purpose of this memo is to review some of the reasons for the recent decision to drop the USBR Lab located in Boise, Idaho and switch to a commercial lab (At this juncture we have selected Basic Laboratories in Redding, California).

Three critical points:

1) During initial review of the 1998 and 1999 water quality sampling data, it was apparent that there were possible quality control concerns (e.g., severe contamination, no formal data validation). These were not identified as field or laboratory issues.
2) Subsequently, USBR Sacramento completed a lab audit of the Boulder City (NV) lab where trace metals were processed. There were QA issues identified and based on these findings, I have recommended dropping all metals from the 1998 data set. Further, based on a methodology that was insufficient to supply the resolution necessary for cadmium reporting, I recommended that cadmium be dropped from the 1999 data set. We are still reviewing the remaining metals.
3) The recent audit of the Boise Lab, where the balance of work was to be completed (nutrients, major ions), several items were noted as requiring improvement. I will defer to the USBR Sacramento Audit Report for details. One finding was that documentation was insufficient, e.g., documentation on calibration methods was inadequate. Based on this, the legal defensibility of samples processed at this lab from 1998 and 1999 appears to have been compromised. As I understand it, last year the lab refused an audit.

In sum, nearly all of the data from the last two years has been compromised to some degree. The Boulder City lab has cooperated with USBR Sacramento and the QA group is confident that they can complete the work up to the required standards. The Boise Lab has been less responsive.

I encourage and support the selection of a commercial lab for nutrients given the

- short time line to implement the field monitoring
- lack of positive response from the Boise Lab
- desire to have a scientifically useful and defensible data obtained in the 2000 water quality sampling program (inability to apply the 1998 and 1999 data sets to legally defensible scientific analyses)
- it is not appreciably more expensive to move to the commercial lab

4-10-00

MP 470 is involved in the QA portion of the Klamath Basin Water Quality Monitoring Project. One of MP470's responsibilities in the project is to procure a laboratory that will be able to analyze a majority of the parameters for the project in a timely manner and provide supporting quality control data and documentation.

At the onset of the project, the program manager selected the USBR Pacific Northwest Regional laboratory (PNR lab) to analyze the nutrient parameters while the USBR Lower Colorado Regional laboratory (LCR lab) was selected to analyze the metal parameters.

The following concerns were raised in regard to the USBR Pacific Northwest Regional laboratory:

1. Uncertainty if the PNR lab could handle the workload from the project – especially the synoptic work.

2. The PNR lab was not able to perform the following analysis- BOD, chlorophyll a, and macrophyte analysis.

3. With the project slated to start in a few weeks, the PNR lab could not make a commitment if they could perform the work for the project.

4. Laboratory cost was based on hourly charges and a fixed dollar amount could not be derived for budgetary purposes. The alternative lab provided guaranteed analytical cost per project quote.

5. All re-analysis were to be charged at full cost; with budgetary constraints the project could go over allocated funds. The alternative lab provided reanalysis at no additional charge if the analytical results were different.

6. The PNR lab did not routinely provide QC summary reports for their data and this would have delayed data verification. The alternative lab provided QC summary reports with all of their data packages.

7. The PNR lab had an average turn around time of one month while the alternative lab had an average turn around time of 10 days.

8. If the PNR lab were able to perform the routine sampling events, splitting the routine work from the synoptic sampling events between two laboratories would introduce more analytical variances.

APPENDIX B: QUALITY ASSURANCE PROGRAM PLAN (QAPP)

Project/Task Organization

The Klamath Basin Water Quality Monitoring Program was operated out of the Klamath Falls Office of the Bureau of Reclamation (KF-Reclamation). This office was responsible for overall field operations, sampling, and monitoring in the upper watershed. The Regional Office in Sacramento provided planning and quality assurance (QA) support. The U.S. Forest Service (USFS) provided field sampling and monitoring assistance in the lower watershed. PacifiCorp (PPL) completed field sampling and monitoring at JC Boyle, Copco and Iron Gate Reservoirs. The Hoopa Valley and Yurok Tribes provided monitoring assistance in the Trinity River and the Klamath River below the Trinity River.

Problem Definition/Background

This program provided baseline information on main stem and tributary contributions on the Klamath River for a representative suite of physical, chemical and biological water quality constituents. These constituents were used to characterize water quality in the mainstem Klamath River, identify water quality constituents of concern within selected river reaches and tributaries, and estimate input parameters for water quality models. Water quality issues affecting anadromous fish in the watershed were of special concern.

To achieve these objectives selected physical constituents were measured sub-daily with continuously deployed water quality probes. Chemical and biological sampling occurred at frequencies ranging from several hours to semi-monthly.

Project/Task Description

<u>Sample Sites and Programs</u>: This program monitored mainstem Klamath River and major tributary water quality from Link Dam near Klamath Falls to Young's Bar below the Trinity River approximately 35 river miles from the Pacific Ocean. Six sampling sub-programs were included within this reach:

- Semi-monthly grab samples (Grab)
- 3-day synoptic water quality surveys (Synoptic)
- Continuous deployment of water quality probes (Sonde)
- Benthic algae bulk growth rate study (Algae)
- Water temperature study (Temp)
- Reservoir water quality sampling (Reservoir)

Table B-1 identifies site locations and sampling sub-program. River miles for the mainstem locations refer to distance from the mouth (ocean), while river miles on tributaries refer to distance upstream from the confluence with the Klamath River.

Table B-1 Sample sites and associated water quality sub-programs

Site #	Name	KR-RM	Grab	Synoptic	Sonde	Algae	Temp	Reservoir
1	Klamath River at Link Dam	255	USBR[1]					
2	Miller Island	246	USBR		USBR			
3	KSD at Hwy. 97 (RM 2)	240.5	USBR		USBR			
4	KSD at Hwy. 161	240.5	USBR		USBR			
5	KSD at Diversion Tunnel	240.5	USBR		USBR			
6	KR at Keno Bridge	235	USBR		USBR			
7	JC Boyle Reservoir	226						PPL
8	KR above Copco	208	USFS		USFS			
9	Copco Reservoir	198						PPL
10	Iron Gate Reservoir	190.2						PPL
11	KR bel Iron Gate Dam	190.1	USFS	USBR	USFS	USBR		
12	KR at Cottonwood Cr.	182				USBR	USBR	
13	KR above Shasta R	176.7		USBR	USBR[2]		USBR	
14	Shasta R (RM 0.0)	176		USBR				
15	Shasta R (RM 0.5)	176	USFS		USFS			
16	KR at Walker Rd. Bridge	156					USBR	
17	KR above Scott R	143.5		USBR	USBR[2]		USBR	
18	Scott R (RM 0.0)	143		USBR	USBR[2]			
19	Scott River (RM 1)	143					USBR	
20	Scott River (@USGS gage) (RM 23.4)	143	USFS		USFS			
21	KR below Seiad Valley (@USGS gage)	128.9	USFS	USBR	USFS			
22	Salmon River (@USGS gage) RM 1.0	66			USFS			
23	Trinity R nr Hoopa (@USGS gage) RM 12.4	43.5			Hoopa			
24	KR near Young's Bar	35			Yurok			

[1] Includes monthly trace elements screening suite

[2] Only during synoptic survey

Data Quality Objectives for Measurement Data

<u>Scope of Work</u>

This program was scheduled to run between April and December 2000. Chemical, biological, and physical parameters impacting the water quality for aquatic life in the river were measured. Uninterrupted physical measurements were interrelated with the operation of dams. The low concentration of dissolved oxygen and high water temperature has impaired this watershed. High turbidity and nutrient loading correlate to water degradation. The hardness of the water influenced the toxicity of cadmium, chromium, copper, lead, nickel, silver, and zinc to aquatic life.

Data Assessment

Table B-2 summarizes the acceptance levels for the external check samples submitted to the laboratories with the production samples. All external check samples submitted to the laboratories were double-blind (sample was not identified as an external check sample). To evaluate external QA check samples, the Bureau of Reclamation's Environmental Monitoring Branch in Sacramento, CA followed protocol outlined in their QA SOP (USBR, 2000). Part of this assessment process may have involved the reanalysis of external QA check samples for project parameters or the whole project for certain parameters if external QA check sample results were not confirmed upon reanalysis. The laboratory's quality control (QC) check samples must also meet certain levels of acceptability when analyzed with the production samples. Part of the data assessment process involved checking these laboratory QC check sample results to ensure they were within acceptable ranges. If a laboratory QC check sample failed to demonstrate an acceptable result, the anomaly was explained with a footnote or included in the case narrative section of the data report. In order to ensure data quality, QA personnel assessed laboratory data packages to determine if all samples were analyzed within the holding times.

Table B-2 Data quality objectives

Parameters	Reporting Limit (mg/l)	Accuracy (% Recovery)	Precision (% RPD)	Completeness (%)	Corrective Actions
Ammonia	0.05 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
BOD	3 mg/l	78% - 128%	Not Established	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Chlorophyll a	10 mg/m3	No Criteria	Not Established	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Benthic Algae: Chlor a	11 mg/m3	No Criteria	Not Established	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Benthic Algae: AFDW	Not Established	No Criteria	Not Established	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Nitrate + Nitrite as N	0.05 mg/l	75%-125%	0%-20%	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Ortho Phosphorus	0.05 mg/l	75%-125%	0%-20%	90%	Re-analyze sample and if not confirmed Re-analyze the batch
TKN	0.2 mg/l	75%-125%	0%-20%	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Total Phosphorus	0.05 mg/l	75%-125%	0%-20%	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Alkalinity	1.4 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Organic Nitrogen	Not Established	No Criteria	Not Established	Not Established	
Organic Phosphorous	Not Established	No Criteria	Not Established	Not Established	
Aluminum	0.02 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Antimony	0.001mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Arsenic	0.001 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Cadmium	0.0005 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Calcium	0.1 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Chromium	0.001 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Copper	0.0003 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Iron	0.05 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Lead	0.001 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Magnesium	0.1 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Mercury	0.005 ug/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Nickel	0.001 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Selenium	0.001 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Silver	0.001 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
TDS	2 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Thallium	0.001 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Zinc	0.010 mg/l	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch

RL = Reporting Limit [ ] = If concentration of determination is....

Sampling Process Design (Experimental Design)

This program was divided into six different sub-programs; each designed to provide an overall assessment of the Klamath River watershed and data for modeling the basin.

Semi-monthly Grab Samples

Water quality grab samples were collected twice a month between May 1 and November 15, 2000. The TDS, alkalinity, nutrients, chlorophyll a, and BOD were measured. The turbidity was measured using a portable instrument when the grab sample was collected. Klamath Falls' personnel collected samples from the upper most five grab-sample sites and the US Forest Service collected samples at Copco Reservoir, KR below Iron Gate Dam, Shasta River, Scott River, and KR below Seiad Valley. Once a month, the trace elements potentially important to aquatic life (Ag, Al, Ar, Cd, Cr, Cu, Fe, Hg, Mg, Ni, Pb, Se, Sb, Tl, and Zn) plus Ca and Mg were sampled at Hwy 97 KSD, Link Dam, Keno Bridge, and below Iron Gate Dam. Three QA samples were added to the production samples to document lab accuracy. The environmental water for the QA samples was collected at KSD at Hwy 97. Also, a rinseate blank was prepared alternately each sampling period by the two field sampling groups to check sampling practices. Entries into the field logbooks, field sheets, and chain of custody (COC) were completed in the field. Samples were stored in ice-chests containing blue-ice at 4^{o} C. The completed COC was placed in a zip-lock plastic bag in the ice-chest and mailed or delivered to lab.

3-Day Synoptic Water Quality Surveys

Synoptic monitoring measured the diurnal changes in nutrient as well as physical parameters. Three synoptic sampling periods occurred: June 5-7, August 7-9, and September 10-12 (the September survey did not include grab samples). Nutrient levels (including organic nitrogen and organic phosphorous) and physical parameters were measured at the synoptic sites three time a day at approximately 6:00 AM, 11:00 A.M., and 4:00 P.M. at six locations for a period of three days, as per Table B-1. Datasondes at the synoptic sites recorded physical measurements continuously (hourly) during this program. Three (3) QA samples were included with each day's sampling. The samples were retained on site until the end of each day and then mailed to the lab. A liter of water containing suspended chlorophyll a was collected in a light inhibited bottle and place in ice chest.

Continuous Deployment of Water Quality Probes

Physical parameters were measured hourly with Hydrolab Datasondes at 13 sites (see Table B-1). Parameters included temperature, dissolved oxygen, pH, specific conductance, and redox. Datasondes were exchanged each week, and transported to Klamath Fall's field-operations center in Klamath Falls, where they were downloaded, cleaned, calibrated, and readied for field deployment the following week. The upper basin sites were serviced by USBR; while USFS serviced probes from "above Copco Reservoir" to the "Salmon River." The Hoopa and Yurok Tribes serviced "Trinity River" and "Klamath River at Young's Bar," respectively. Table B-1 outlines the programs, locations, and agency in charge.

Benthic Algae Bulk Growth Rate Study

The benthic algae monitoring program occurred at two sites and samples were collected during three, four- to five-week sampling periods in May, July, and September. Artificial substrates in the form of ceramic tiles and glass slides were used to monitor algal growth. The ceramic tiles were used for qualitative analyses, while the glass slides were collected and sent to a laboratory for chlorophyll a and ash free dry weight. Floating periphyton samplers were used to hold the glass slides suspended in the river to minimize grazing impacts. Ceramic tiles were placed in the river for a minimum of several days prior to the initial sampling. At the commencement of each sampling period the substrates were scrubbed clean with a nylon brush. Sites were visited weekly and substrate conditions on the tiles were photographed and reported in a narrative. Four slides were removed from the periphyton samplers: one for chlorophyll a analysis and three for ash-free dry weight determination. The glass slides intended for laboratory analysis were placed in glass bottles wrapped in aluminum foil and transported to the laboratory on dry ice. Nitrogen nutrients and orthophosphate were also collected for this program. Between sampling periods, the ceramic tiles remain in the river, but the periphyton samplers were removed. The process was repeated for the next sampling period.

Water Temperature Study

Water temperature was monitored with remote logging thermocouples at five locations in the Klamath River and tributaries between Iron Gate Dam and Seiad Valley (See Table B-1). Logger sampling frequency was one hour. These data were intended to augment Datasonde deployments and provide information for temperature analysis and modeling.

Reservoir Water Quality Sampling

Surveys of the three reservoirs consisted of monthly depth profiles of the same physical parameters measured in the rivers at the surface and at one to two meter intervals above and below the photic boundary. In addition, temperature loggers recorded at hourly intervals at multiple depths in each reservoir. Finally, water quality sampling of JC Boyle, Copco, and Iron Gate Reservoirs occurred May, early June, early August, and mid-September. Nutrient, BOD, and chlorophyll a was collected at three depths corresponding to a representative epilimnion, metalimnion, and hypolimnion sample. Due to its relative shallow depth, JC Boyle was only sampled at two depths (near-surface and near-bottom). The monthly profiles and temperature loggers continued through November.

Chemical and Biological Constituents of Interest

Chemical and biological water quality constituents of interest that require laboratory analysis were limited to the semi-monthly-nonmetal and monthly-metal grab samples (Grab), 3-day synoptic water quality surveys (SS), benthic algae bulk growth rate study (Algae), and reservoir water quality sampling (Reservoir) as shown in Table B-3.

Sampling Method Requirements

For field sampling protocol, the "Klamath River Water Quality Standard Field Sampling Operating Procedure" was used.

All water samples were collected using the grab-sample method. A ***churn splitter or sample bottle (for unfiltered samples)*** was used to collect water from the river's shore. A van Dorn or Kemmerer was used to collect water from bridges and reservoirs. Before use, the churn splitter was rinsed three times with environmental water and water was run through the push valve. The van Dorn or Kemmerer or pump (reservoir only) was also rinsed in the river or reservoir three times before use. The Field SOP instructs how the monitoring and sampling was performed and associated procedures for documenting the field activities. Water samples designated as "dissolved" (filtered) were first pumped through a 0.45um filter.

A Datasonde was used to measure the physical parameters (pH, specific conductance, dissolved oxygen, turbidity and water temperature) of the environmental water. A turbidity meter was used to measure this physical parameter.

Table B-3 Sampling sub-programs and chemical constituents requiring laboratory analysis

Constituent	Grab	S.S.	Sonde	Algae	Temp	Reservoir
Aquatic Life Metals	X					
Hg	X					
NH_4	X	X				X
Total Kjeldahl N	X	X				X
$NO_2 + NO_3$	X	X				X
Total P	X	X				X
Ortho PO_4	X	X				X
Organic P dissolved		X				
Organic N dissolved		X				
TDS	X					
Ca, Mg	X					
HCO_3, CO_3 (Alkalinity)	X					
BOD	X					X
Chlorophyll A	X					X
Benthic algae (Chlor a and AFDW)				X		

Sample Handling and Custody Requirements

Water samples were collected in high-density polyethylene (HDPE) bottles and preserved according to EPA, Standard Methods, or other approved analytical methodology. Samples collected in the field were labeled with:

- Sample identification
- Preservatives used
- Constituent analyses required
- Date and time sampled
- Samplers initials

Sample volume was based on analytical requirements and listed in Table B-4. Upon collection in the field, water and biological samples were placed in ice chests with a temperature of four degrees Celsius. All samples collected in the field required a chain of custody sheet and a field sheet. The chain of custody sheet and the field sheet clearly documented all the samples collected during that sampling period, associated sample identification numbers, and the date and time of collection for each sample. The COC was placed in the ice chest in a zip-lock plastic bag. A custody seal was attached to the ice chest by the field sampler. The ice chests were then given to a commercial package carrier or laboratory courier. The original COC sheet was kept on file at the laboratory and the other copy was returned to the USBR Regional Office.

Analytical Method Requirements

The analyses selected were based on previous analyses of basin water and identified requirements for water quality models. The criteria limits for freshwater aquatic life were used to select the methods of analyses. The USBR - Lower Colorado Regional Laboratory in Boulder City, NV was responsible for analyzing the water samples for TDS, calcium, magnesium, carbonate, bicarbonate, aluminum, antimony, arsenic, cadmium, chromium, copper, iron, lead, nickel, selenium, silver, thallium, and zinc. The samples requiring TKN, ammonia, nitrate + nitrite as N, total P, ortho P, BOD, chlorophyll-A, organic phosphorus, organic nitrogen, and benthic algae were sent to Basic Laboratory, located in Redding, CA. NEL Laboratories, located in Reno, NV performed mercury analysis. The methods presented in Table B-4 were utilized to determine the concentrations of these analyses in the water samples.

Table B-4 Analytical methods

Inorganic Parameters	EPA	SM	Other
Aluminum	6010		
Antimony	6020		
Arsenic	6020		
Cadmium	6020		
Chromium	6020		
Copper	6020		
Iron	6020		
Lead	6020		
Nickel	6010		
Mercury	7470A		
Selenium	6020		
Silver	6020		
Thallium	6020		
Zinc	6020		
Ammonia		4500 NH3	
Total Kjeldahl Nitrogen		4500 NORG	
Nitrate + Nitrite, as N		4500 NO3	
Ortho-Phosphate		4500 P	
Total phosphorus		4500 P	
Organic Nitrogen (dissolved)		4500	
Organic Phosphorus (dissolved)		4500	
Bicarbonate			USDA, bk60, p98 & 146
Carbonate			USDA, bk60, p98 & 146
TDS		2540C	
Calcium	6010		
Magnesium	6010		
BOD		5210	
Chlorophyll A		10200H	
Benthic algae		10400b 3a	

Sample Bottle Requirements

The bottles used to collect the specified constituents, including required preservative and hold times are presented in Table B-5. Labels were attached to bottles and information about the samples written on labels with waterproof ink. High-density polyethylene (HDPE) bottles were used. The sample bottles used for trace metals and mercury were "level 1" certified to ensure bottle contamination did not effect analytical results. All bottles were rinsed three times with the environmental water prior to filling with sample. Any filtration required was done from the churn splitter in the field. All acid preservation required was done in field after sample collection. The chlorophyll a sample bottle was wrapped with aluminum foil after sample collection to prevent light from affecting the sample. The benthic algae samples were placed (individually) in 125 ml bottles for transportation and wrapped in aluminum foil to prevent light from affecting the sample.

Table B-5 Sample filter requirements, bottle volumes, preservatives, and hold times

Test	Filtered	Container	Preservatives	Hold Time
Trace Metals (total)	N	500 ml	$4^{o}C$, HNO_3	6 months
Mercury (total)	N	250 ml	$4^{o}C$, HNO_3	28 days
NH4, (NO2+NO3)N, TKN, total P	N	1,000 ml	$4^{o}C$, H_2SO_4	28 days
Ortho Phosphate	N	500 ml	$4^{o}C$, none	48 hours
Organic P	Y	500 ml	$4^{o}C$, none	48 hours
Organic N	Y	500 ml	$4^{o}C$, none	48 hours
Total Alkalinity	N	250 ml	$4^{o}C$, none	14 days
TDS	Y	250 ml	$4^{o}C$, none	14 days
Ca, Mg	Y	250 ml	$4^{o}C$, HNO_3	6 months
BOD	N	1,000 ml	$4^{o}C$, none	24 hours
Chlorophyll A	N	1,000 ml Alumin. foil wrap	$4^{o}C$, none	48 hours
Benthic algae	n/a	Glass slide	Dry Ice	48 hours

Quality Control Requirements

To check laboratory accuracy, precision, and contamination, field personnel incorporated one blank sample, one duplicate sample, and one spike sample or one QA reference sample per sampling period for the routine phase and per day for the synoptic survey. Field samplers labeled these external QA check samples with identifications similar to production samples so that they could pass as double blind samples. The QA Officer ensured that field personnel properly prepare external QA check samples. The Klamath office and the Forest Service alternated including a rinsate blank of their field sampling equipment each sampling period. The rinsate blank included a sample bottle for each constituent. The laboratories incorporated their own QC check samples, including spikes, duplicates and blanks, to ensure data reliability. For specific rates of laboratory QC check sample incorporations, one needs to refer to the laboratory QA manual. Laboratory QC check sample results were reported to the client as QC summary reports.

The specific standard operating procedures used by the Lower Colorado Regional Laboratory, Basic Laboratory, and NEL Laboratories to analyze the samples for this project can be found in their QA manuals.

Instrument Calibration and Frequency

The laboratory performed instrument calibrations following the procedures and frequencies stated in the analytical methods for each parameter.

Each Datasonde instrument was calibrated before each day it was used in the field. These calibrations followed the manufacturer's instructions as outlined in the calibration procedures outlined in the appendix. Field personnel recorded Datasonde calibrations on calibration sheets, which were filed at the USBR Klamath Basin area office.

Assessment and Response Actions

Review of field activities was the responsibility of the Project Manager, in conjunction with Reclamation's Environmental Monitoring Branch (MP-157) located in Sacramento, CA. Performance of the field crew was evaluated once a year.

Prior to selecting a laboratory as a participant in this program, their analytical skill was evaluated through the use of performance samples. After demonstrating acceptable results on these performance samples, a system audit was performed on these laboratories. The system audit consisted of first reviewing the laboratory's QA manual and EPA WP/WS performance study results for the past three years. After reviewing these documents, a USBR audit team visited the laboratories to make certain they had everything in place to perform the work.

Management and MP-157 were notified of any changes to the sampling plan or the QAPP.

Data Review, Validation and Verification Requirements

The Bureau of Reclamation's Environmental Monitoring Branch in Sacramento, CA. (RO-Reclamation) reviewed and verified all data generated from this program. RO-Reclamation followed protocol outlined in their QA SOP (revised November 1999) to review and verify the data from this program.

The laboratory's QC check samples must meet certain levels of acceptability when analyzed with the production samples. These levels of acceptability were established using control charts or set at certain limits found in the methods. Part of the data verification process involved checking these laboratory QC check sample results to ensure they were within acceptable ranges. If a laboratory QC check sample failed to demonstrate an acceptable result, the anomaly was explained with a footnote or included in the case narrative section of the data report. In order to ensure data quality, QA personnel assessed laboratory data packages to determine if all samples were analyzed within there holding times.

This project's goal was 100% completeness for samples submitted for testing to the laboratories.

Review and Verification Methods

When RO-Reclamation incorporates external quality assurance (QA) check samples into a batch of production samples submitted to a laboratory, the laboratory must meet certain standards of acceptance on these QA check samples for the data to be approved as reliable. For this project, the standards of acceptability for the external QA check samples were:

Duplicates: For values > 5X Reporting Limit, RPD $\leq$ 20%
For values $\leq$ 5X Reporting Limit, values may vary $\pm$ 1X Reporting Limit
(Duplicates constitute at least 10 percent of the samples)

Spikes: Recovery should be 80%-120%
Limit does not apply when sample value exceeds spike concentration by $\geq$ 5 times
(Spikes constitute at least 5 percent of the samples)

Reference Materials: Recovery should be 80%-120% of certified value for values $\geq$ 20X Reporting Limit
For values < 20X Reporting Limit, recovery should be $\pm$ 2X Reporting Limit from the certified value

Blanks: Blank concentration should be less than 10% of lowest sample concentration or less than two times the reporting limit.
(Blanks constitute at least 5 percent of the samples)

Reclamation used the following equations to validate data:

Relative percent difference: A statistic for evaluating the precision of a replicate set. For replicate results X1 and X2:

$$RPD=((X1-X2)/(X1+X2/2))x100$$

Completeness: The amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under correct normal operations. It is usually expressed as a percentage:

$$\% \text{ completeness} = V/n \times 100$$

where: V= number of measurements judged valid
n = total number of measurements

Percent recovery: A measure of accuracy determined from comparison of a reported spike value to its true spike concentration:

% Rec. =((observed conc.-sample conc.)/(true spike conc.)) x 100

Accuracy: Accuracy is a measure of the bias inherent in a system or the degree of agreement of a measurement with an accepted reference or true value. It is most frequently expressed as percent recovery.

Precision: A measurement of mutual agreement (or variability) among individual measurements of the same property, usually under prescribed similar conditions.

Precision is usually expressed in terms of relative percent difference, but can be expressed in terms of range.

Range: The difference between the largest and smallest numbers in a set of numbers.

All data entered into tables by RO-Reclamation were subjected to a thorough secondary review before being released to clients.

Reconciliation with Data Quality Objectives (DQO)

After each sampling event, calculations and determinations for precision, completeness and accuracy were made immediately and corrective actions implemented if needed. If data quality indicators did not meet the project's specifications, data may have been discarded and re-sampling may have occurred. The cause of failure will be evaluated. If the cause was due to equipment failure, calibration/maintenance techniques will be reassessed and improved. If the problem is determined to be a sampling error, team members will be retrained. If the problem is laboratory related, the laboratory program manager will be contacted and corrective actions implemented. Any limitations on data use will be detailed in both interim and final reports and other documentation as needed.

This QAPP will be revised if DQO failure occurs while following protocol. Revisions will be submitted to the review team, including the quality assurance group and technical advisors for approval.

APPENDIX C: FIELD SAMPLING SOP FOR KLAMATH BASIN BASELINE MONITORING PROGRAM

Basic Checklist

Prior to leaving the office

- Assemble sampling equipment - see Klamath Basin Program Equipment & Supplies List
- Check all sampling equipment
- Carry cell phone and telephone number directory
- Check bottles needed for sampling - see Grab and Synoptic Bottles Lists below (Table , Table C-2)
- Check chemicals and blue ice (Table , Table)
- Test equipment batteries and carry spares
- Calibrate instruments against standards
- Prepare analysis forms
- Have "Sharpie pen" for labels and ball point pens for writing
- Pack field notebook, field sheets, and chain of custody (COC) sheets

At sampling site

- Label bottles
- Collect all necessary samples (See Bottle List below)
- Filter and preserve samples correctly
- Store samples properly
- Prepare field logbook, COC sheet, and field sheet.
- Prepare shipping coolers and mailing forms

After sampling

- Recheck calibration of equipment
- Clean and store field equipment

Grab Sample

1. The churn splitter is used to collect a water grab sample. Care is exercised not to disturb the bottom sediment while sampling. Avoid surface debris while collecting. The churn splitter is rinsed with environmental water three times prior to collecting sample and water is run through the pour spout. Do not disturb the location where sample is to be taken from with discarded rinse water. If the sample is collected from the bank of the river, the water should be collected from a location of good flow. If walking into the river is required, collect from a location up-stream of wader.
2. The preferred method of collecting whole (unfiltered) samples is to dip the sample bottle with mouth pointed up-stream, in the river current. The bottle is rinsed three times with environmental before collection. When sampling in system reservoirs collect environmental water from the desired depth for rinsing the bottles. If sample bottles are pre-preserved do not rinse with environmental water. Filtered and QA samples must be collected in a churn splitter.

Table C-1 Grab sample bottle list

Constituents	Bottle	Preparation	Lab
Trace Elements : (with the exception of Hg, see below)	500 ml HDPE **(level one)**	2 ml $HN0_3$	LC Reg.
Nutrients:NH4,(NO_2+NO_3) as N,TKN, Total P	1,000 ml HDPE	4 ml $H2SO_4$	Basic
Total Alkalinity: CO_3 + HCO_3	250 ml HDPE	none	LC Reg.
Mercury (hg)	250 ml HDPE **(level one)**	1 ml $HN0_3$	NEL
Ortho PO_4	500 ml HDPE	none	Basic
BOD	1,000 ml HDPE	none	Basic
Chlorophyll A	1,000 Glass	Amber	Basic
Ca + Mg	250 ml HDPE	**filter then** 1 ml $HN0_3$	LC Reg.
TDS	250 ml HDPE	**filter**	LC Reg.

Table C-2 Synoptic survey bottle list

Constituents	Bottle	Preparation	Lab
Nutrients:NH_4,(NO_2+NO_3)as N,TKN, Total P	1,000 ml HDPE	4 ml H_2SO_4	Basic
Ortho PO_4	500 ml HDPE	none	Basic
Organic P	500 ml HDPE	**filter**	Basic
Organic N	500 ml HDPE	**filter**	Basic

Van Dorn, Suspended-Sediment Water, and Kemmerer Sampler

The suspended-sediment water sampler, van Dorn, or Kemmerer (water sampler) is used to collect samples from a reservoir or from a bridge. Rinse the water sampler with environmental water three times at all sampling sites prior to use. In reservoirs it is not feasible to rinse the water sampler with environmental water three times because the sampler must pass vertically through the water column en route to the desired depth. However, it is advisable to sample shallow depths first, and rinsing three times with near surface environmental water prior to the surface sample.

The suspended sediment water sampler is lowered to the desire depth at a constant rate and then raised. The water collected in the sample bottle is poured into the churn splitter. The other water samplers are lowered, the trigger mechanism is activated, and then raised to the surface and the water is poured into a churn splitter. The water sampler is cleaned after use in the field by 1) carefully inspecting and removing any foreign material, 2) rinsing exterior, 3) rinsing interior three times with de-ionized water.

Reservoir Sampling with a Pump

Under certain circumstances reservoir samples will be completed using a pump to draw water from various depths. The pump is a battery operated 12v DC submersible pump (Ben Meadows Model DC60, ABS body, stainless steel propellers and chemically inert seals) fitted with 30 m of 3/8" ID Tygon tubing. Prior to sampling and between sampling depths within a reservoir, the pump and tubing assembly should be rinsed with 5 liters of environmental water (5 tube volumes). Sampling can be carried out directly to the sample bottles for all but the QA samples, in which case water is pumped to a churn splitter and QA samples drawn accordingly. Pump assembly and tubing is cleaned by pumping a minimum of 2L of DI water through the pumping system between sample locations. Equipment is cleaned at the end of the sampling day by pumping a minimum of 2L of DI water through pumping system.

Churn Splitter

The churn allows different sub-sample volumes to be obtained from the composite sample while still maintaining the same basic chemical and physical properties of the original sample. The volume of the churn splitter limits the volume of sample that can be divided. Suspended inorganic sediments coarser than 62 micrometers (um) cannot be split. Samples may be taken from a plastic (Nalgene™) churn splitter for analysis of all dissolved and suspended inorganic constituents except suspended sediment (>62 um), organic compounds (including TOC, SOC, DOC, oil and grease, and pesticides), bacteria and dissolved oxygen. A Teflon™ lined churn splitter is required for organic compound constituents. Organic P and N can be collected and dispensed from Nalgene™ churn splitter.

Sub-samples totaling 10 liters may be withdrawn from the 14-liter churn, whereas, up to 5 liters may be withdrawn from the 8-liter churn. The 4 liters remaining in the 14-liter churn and the 3 liters remaining in the 8-liter churn should not be used for total, total recoverable, or suspended material (i.e., unfiltered) sub-samples because they will not be representative. However, the sample mixture remaining in either churn may be used for filtered sub-samples for the determination of dissolved constituents.

The procedure for cleaning and use of the churn splitter is as follows:

1. The Klamath Falls office will clean the churn splitters between sampling events. They will use gloves while doing this. After removing foreign material from churn splitter with nylon brush and soap & water, the churn splitter is rinsed with water.

2. Pour about 200 ml of dilute (i.e. 6%) nitric acid into churn splitter and wet all inside surfaces of churn splitter with dilute acid. Acid is run through the pour spout. Decant dilute acid down drain with good flow of water.

3. Rinse the churn splitter with DI water three times. Drain DI water from the spout during each rinse. The churn splitter is now ready for field use.

4. Label all the sub-sample containers. Set aside the **TDS** and **Ca & Mg** (Organic Nitrogen and Organic Phosphorous for the synoptic survey) bottles that will contain filtered environmental water. The remaining bottles (unfiltered samples) are rinsed with environmental water when the churn splitter is rinsed, see step 5 below. Only rinse the bottles that will contain water collected at the current site. Do not rinse bottles that have been pre-preserved.

5. The churn splitter is rinsed with environmental water three times in the field at the first site and at each subsequent site prior to sampling. For reservoir sampling, the churn is rinsed three times with environmental water collected from the desired sampling depth. Drain environmental water through pour spout. Rinse bottles with environmental water (as per step 4, above). This activity can be done

while collecting sample at river or reservoir. Between river sampling sites and between reservoir sampling depths the churn is rinsed three times with DI water.

6. If QA samples are not collected at a site, then a maximum of 5 liters are required at each site. Fill the churn splitter to have enough water for all samples. The last 3 to 4 liters of sample in churn cannot be used for non-filtered samples (i.e. total, total recoverable, or suspended material sample). It is important to completely fill the 8-liter churn splitter to have adequate water supply.

7. At the QA site on KSD @ Hwy 97 and Iron Gate Reservoir epilimnion, the churn splitter must be filled more than once. Duplicate and triplicate (spike or reference) samples are collected. Two sample bottles (duplicate and regular) are filled from the same churn-splitter volume for each of the constituents. No spike is available for chlorophyll a. For some of the constituents, three sample bottles of environmental water are filled from one-volume of churn-splitter water; these triplicate water samples are collected in bottles for mercury, trace metals, Mg & Ca, ortho phosphate, and nutrients. All three bottles for these constituents must be collected from the same churn-splitter volume. The Klamath Falls field sampler adds a spike volume to the triplicate sample bottle of environmental water for these constituents. A third bottle of environmental water is not collected for alkalinity, BOD, and TDS spike samples; a reference solution is poured into the triplicate bottle by the sampler from the Klamath Office for these constituents.

8. It is sometimes necessary to composite water into churn splitter from a sampling devise. A van Dorn, kemmerer, or a suspended sediment sampler can be used from a bridge or a boat. Where a churn splitter cannot be filled with one of these samplers from the shore or boat without disturbing the sampling area, one sample bottle is used repeatedly to fill the churn splitter. Swirl water in sample bottle prior to pouring into the churn splitter in order to minimize the amount of suspended material lost in transferring from the bottle to the churn. This swirling procedure is used when collecting water in the churn splitter from other samplers also. As stated in above, it is preferred to collect unfiltered environmental water directly into a sample bottle. QA samples (regular, duplicate, and triplicate) must be dispensed from a churn splitter.

9. Churn the sample at a uniform rate of about 9 inches per second (in/s). The disc should touch the bottom of the tank on every stroke and the stroke length should be as long as possible without breaking the water surface. If the churning rate is significantly greater than 9 in/s or if the disc breaks the water surface, excessive air is introduced into the sample and may change the dissolved gases, bicarbonate, pH, and other characteristics of the sample. On the other hand, inadequate stirring may result in non-representative sub-samples.

10. After churning the sample in the splitter for about 10 strokes to assure uniform dispersion of the suspended material, begin the withdrawal of sub-samples. As sub-samples are withdrawn and the volume of sample in the churn decreases, maintain the churning rate of about 9 in/s. If a break in withdrawals is necessary, the stirring rate must be reestablished (i.e., 10 strokes) before withdrawals are continued.

11. While operating the churn, withdraw an adequate volume of sample to field rinse bottles for total, total recoverable, and suspended material sub samples (rinse each bottle three times).

12. Withdraw sub-samples for total, total recoverable, or suspended analyses first. The first sub-sample withdrawn should be the largest sub-sample required (usually 1 liter of the sample).

13. After all the required total or suspended material sub-samples have been withdrawn, the sample remaining in the churn may be filtered for sub-samples required for dissolved constituents. Remember to field rinse bottles three times with filtered sample water prior to filling. Procedures for filtering and preserving samples are described later.

14. After all filtered sub-samples have been withdrawn, empty the churn and clean the mixing tank and churning disc thoroughly with de-ionized water.

Filtering Water Samples

Water samples are filtered using a 0.45um inline filter and a peristaltic pump. The inlet sample line to the pump is placed in the churn splitter and the inline filter is attached to the exit sample line of the pump. About a 500-ml of water is pumped through filter before any water is collected. This water should not be used to rinse sample bottles. After using pump at each sample, discard inline filter and pump about a 500-ml of DI water through tubing.

If the peristaltic pump fails or is unusable for any reason, samples can be filtered with the filter syringe. The filter syringe is used as follows: Disassemble a clean 100-ml syringe. Place a new green filter on the end of the syringe. Wash the inside of syringe and barrel with environmental water three times and discard water. Fill sample barrel with sample water. Push 10-15 ml of water through the syringe and rinse the sample bottle. Shake sample bottle and discard water. Now fill the sample bottle with filtered water using the syringe-filter procedure. Refill the syringe if more sample water is needed and the filter has not plugged. If filter is plugged, use a new filter and continue.

Water Sample Preservation

Physical preservation techniques are used for all samples and include cooling and keeping sample out of sunlight. Water samples are also preserved with chemicals to prevent degradation of the constituent before they are analyzed. Specific requirements for the field preservation of samples are contained Table C-1.

<u>Trace Elements and Metals</u>

Preserve trace elements and metals in water for 6 months hold time with nitric acid; mercury has a hold time of only 28 days. One ml of 70% nitric acid is used with each 250 ml of sample. The sample is also chilled to 4^oC in field.

<u>Nutrients</u>

The NH4, $NO_2 + NO_3$, TKN, and total P sample in a 1,000 ml bottle require 4 ml of H_2SO_4 and have a hold time of 28 days.

<u>Chlorophyll a, Orthophosphate, BOD and Organic P and N</u>

Chlorophyll a, orthophosphate, BOD, and organic P and N samples have 48-hour hold times. Refrigerate or chill water samples and delivered to the lab within *hold time*. Chlorophyll a samples are immediately wrapped with aluminum foil to keep sunlight from sample and stored in the dark.

Other Water Samples

Refrigerate or chill water samples and delivered to the lab within *hold time*. These samples are not preserved chemically and have a hold time as shown on the Bottle List.

If in doubt about any sample, it is best to keep it chilled and out of the sunlight.

Dispensing Acid from Ampoule for Preserving Samples

Rubber latex or vinyl gloves and safety glasses are worn to prevent acid from contacting hands or eyes while preserving samples with acid.

Sample Handling and Transportation

Sample handling and transportation vary depending upon the analysis requested, sample preservation requirements, and the distance to the laboratory. However, once preserved, some samples will remain stable for long periods. Samples with short hold times should be mailed by overnight courier or mail service. All samples on this program will be shipped on the day they are collected. (If samples are not shipped on the day they are collected they must be delivered in person to the labs the following day.)

When shipping samples, it is preferable to pack them in an ice chest. This provides protection, insulation, and containment in case of breakage or spillage. When shipping samples that require chilling, pack plenty of frozen "blue" ice with the sample. Seal ice chests securely with duct or packing tape to ensure they do not accidentally open.

Sample Quality Control and Assurance

Objective

Quality control of samples during collection, processing, and transportation is an integral part of any sample-quality-control program. Quality control procedures are used to assess potential sampling and analytical bias.

Techniques

Rinseate Blanks
A rinseate blank tests sampling equipment for chemical contamination. After sampling equipment has been cleaned between sites, the rinseate blank is collected. Rinseate blanks are prepared by pouring DI water onto sample collection equipment and wetting all internal surfaces. The rinseate water is then collected into churn splitter. Collect sample bottles for each constituent that is part of program. The sample bottles are washed three times with the reinstate water before collection. Filtered constituents are collected using a peristaltic pump and filter. Preservation is added to samples requiring it. A rinseate blank has a QA abbreviation of "RB".

Production Samples
A production sample measures chemical concentrations in the environmental water and has the QA abbreviation of "P".

Duplicate Samples
A split sample is a portion or sub-sample of a total sample. This sample is used to determine analytical precision within a laboratory. In contrast to duplicate samples, replicate samples refer to two or more discrete samples collected at the same location and time. A duplicate sample has a QA abbreviation of "D".

Regular Samples
A regular sample is a production sample and has an associated duplicate. A regular sample has a QA abbreviation of "R".

Triplicate Sample (Field Spikes and Reference Solutions)
These are chemical solutions prepared by MP-157's QA group and are added to specified volumes of environmental water or directly to sample bottle. A graduated cylinder is used to measure the volume of environmental water used. When adding the prepared chemical solutions (e.g., vial) to environmental water, rinse vials with environmental water and add to sample bottle to ensure all chemical solution is included in sample. It is important to maintain the proper volume when carrying out this step. Note lot number of reference solutions in field note book.

In some cases, the triplicate (reference solution)is not mixed with environmental sample, but used to fill the bottle completely. A Triplicate sample has a QA abbreviation of "S".

Standards
Standards or reference materials are used for calibration of equipment that measures an environmental parameter. Use of reference standards is an integral component of quality control. Both water-quality-field equipment and laboratory equipment must be periodically calibrated to assure the instruments accuracy. The automated water quality field equipment, such as Hydrolab, Foxboro, Hach and Turner turbidity meters require regular calibration. The manufacturer's instructions for calibration and standardization should be closely followed.

<u>Sample Description</u>

1. Sample Identification Number
   A unique sample identification number is used for samples collected at different sites. The same number is used for all constituents collected. A letter prefix of "KBWQ" identifies this program as Klamath Basin Water Quality Program. A four digit number is used to identify site and sample period. These sample identification numbers are pre-selected by the Klamath Office.

2. Field books, chain of custody, and field sheets are written with waterproof ink. Any corrections made to these documents are lined out and initialed and dated. Unused lines in notebook and COC are lined out and notebooks signed by samplers.

3. A field notebook contains enough pages for all sampling dates. Field personnel during sampling carry the retained-field logbook. Past physical measurements and observations are compared to current conditions.

Field Log Sheets

Field personnel complete field sheets. This documents the collection of a sample, sample number, field analyses performed, and the laboratory analyses requested. The person who collected the sample signs the Field Sheet.

Field Sheets include

- Sample identification information (including Field ID)
- Field Measurements
- Sample Types
- Comments

Field sheets provide a convenient system for tracking the monitoring and analysis requests for each site in a particular project. Further, the field ID provides the cross-reference to laboratory results and sampling locations.

Chain of Custody

A chain of custody (COC) accompanies all samples to record possession of samples. Field identification, date and time of collection, laboratory identification, type, and contents as well as other information are recorded on these forms. Throughout sample collection and transport all samples collected are kept in a secured area, an area accessible only to authorized personnel. Upon completion of field collection the COC sheet is delivered to the lab with the samples. Chain of custody sheets are also legally binding and act as a work order for a laboratory. It is critical that the field identification number is properly recorded on both the field sheets and COC forms. Sample collectors, individuals transferring samples, and those receiving samples, all sign the COC. The forms are in triplicate and field personnel should not remove any forms.

Field Notebook

A bound field logbook is used to record field sample collection, field observation, sample treatment, and other pertinent information necessary to reconstruct the sample collection processes. All entries are made in ink. Field logbooks are kept by field crew and on file when the program is complete. All field books are returned to the Klamath Falls USBR Office.

Ringed Field and Calibration Binder

A ringed binder is used to store field sheets and calibration sheets. The binder can be used to store level one clean-bottle certificates, acid purity certificates in ampoules, and contamination certificates of in-line filters, and other appropriate certificates and papers.

Security Shipping Seals

A security seal is attached across the ice chests lid and side. The seal is signed and dated by the sampling personnel. The seal is attached so that it must be broken when the container is opened.

Klamath Basin Program Equipment & Supplies List

Equipment

- Churn splitter
- Peristaltic pump & tubing
- Rope
- Hip waders
- Long handle sampling vessel
- Van Dorn, Kemmerer with messenger
- Cell phone and telephone numbers
- Camera
- Turbidity meter & standards
- Knife
- Clip board
- Notepad
- Safety glasses
- Hydrolab Surveyor 3 and cables
- Sample bottles
- Syringe and filters
- Ice chests and blue ice

Supplies

- Spike solutions (QA samples)
- Rubber latex or vinyl gloves
- 12 in line filters for five sites
- Bottle labels
- Sharpie pens
- Ball point pens
- Maps
- COC sheet
- Field sheet
- Calibration sheet
- 6 data sheets for 5 sites
- Zip bag for COC sheet
- Duct or packing tape
- FedEx or Cal Overnight shipping labels or forms
- 5 to 10 gallons of DI water
- 1-quart plastic cube for used acid ampoules
- Squeeze bottle for DI water
- Brush for equipment cleaning
- Paper towels
- Plastic bucket
- Aluminum foil

Bottle List [for each sample site or QA sample]

- 3 1,000 ml HDPE for BOD, chlorophyll a, and nutrients(NH4, NO2+NO3, TKN, and total P)

- 1 500 ml HDPE **level one** for trace metals
- 1 500 ml HDPE for ortho phosphate
- 1 250 ml HDPE **level one** for Hg
- 3 250 ml HDPE for Ca & Mg, total alkalinity, and TDS

Acid ampoules (each grab site)

- 1 4-ml sulfuric acid for nutrients (or equivalent)
- 4 1-ml nitric acid for trace metals(uses 2), Hg(use 1), and Ca & Mg(use 1),

Laboratory Addresses

NEL Laboratories

4759 Longley Lane, Suite 106
Reno Nevada 89502
1-800-368-5221

Parameter: Hg

Lower Colorado Regional Laboratory

400 Railroad Ave.
Boulder City, Nevada 89005
702-293-8598

Parameters: Ca & Mg, TDS, Total Metals(Al, Cd, Cu, Ni, Pb), Alkalinity (carbonate and bicarbonate)

Basic Laboratory

2218 Railroad Ave
Redding California, 96001
530-243-7234

Parameters: Nutrients (Total P, NO2 + NO3 as N, NH4, TKN), ortho - PO4, BOD, and Chlorophyll A

USBR Addresses:

U.S. Bureau of Reclamation	U.S. Bureau of Reclamation
Klamath Basin Office	Regional Office
6600 Washburn Way,	2800 Cottage Way,
Klamath Falls, OR 97603	Sacramento, CA 95825
541-883-6935	916–978-5285

Calibration and deployment protocols are outlined below.

Calibration Protocol

Hydrolab DataSonde 3 & H2O Calibration Protocol

INTRODUCTION:
Ensure that maintenance is conducted on a weekly basis. Store the instruments with a cup filled 2/3 with deionized water and be certain to always place the LISREF cap on the instrument when not in use. The success and quality of a water quality instrument depends on scheduled maintenance. This is a fundamental understanding if we are to deploy instruments that must meet a high degree of both precision and accuracy. Standards are vital to help ensure that a basis for comparison is not compromised because of introduced sampling bias. As science professionals we are required to uphold the integrity of data required to make statistical representations. The following is provided as a supplemental reference to be used when calibrating hydrolabs. Always refer to the manufacturer=s specifications listed for each parameter. For additional information please refer to the Department of the Interior USGS Western Region Field Manual.

Order of Calibration Sequence:

1st Specific Conductance Sensor
2nd Dissolved Oxygen Sensor
3rd pH Sensor
4th ORP (Redox) Sensor

Specific Conductance Calibration:
Note: It is highly recommended to use PROCOMM PLUS software to calibrate your hydrolab. This is currently the industry standard employed to calibrate hydrolabs. Before calibration, ensure that the calibration standards have not expired. Be very careful during cleaning not to sand, grind down, or deform the six pins which could damage the pins resulting in a flat surface. Very lightly apply only enough force or pressure required to lightly buff and remove residue. The sensor pins must be clean and free of any salt or crystalline residue before attempting a calibration. If the instrument will not calibrate, clean the six pins with isopropyl rubbing alcohol, rinse with deionized water and try again. Bracket the conductivity of your local water with two conductivity standards. Calibrate with a Conductivity Standard that is nearest in value to that of expected sample site. Perform a linearity check with the half-value Standard afterwards. Example: Upper Klamath Lake Specific Conductance is approximately 105 µS/cm. Select a 147 µS/cm Standard and then select a half-value Standard of 74.0 µS/cm.

FIRST: Triple rinse the sensors with deionized water.
Next: Prerinse with the upper Conductivity Standard.
Next: Completely fill the calibration cup above the D.O. membrane with the Conductivity Standard.
Pour slowly to prevent bubbles from forming on the sensors.
Next: Allow the Conductivity sensor 3-5 minutes to stabilize.
Next: Record the *Initial Value* in the calibration log.
Next: Select ***(C)alibrate*** (from the ProcommPlus menu)

Next: Select ***Specific (C)onductance/Resistivity***.
Next: Type the Conductivity Standard value and then press **Enter**. Example: Type ***147*** µS/cm and then press the ***Enter*** key**.**
Next: Record the *Actual Value* in the calibration log.
Next: Discard the 147 standard and rinse with deionized water.
Next: Rinse with deionized water again.
Next: Prerinse with the half-value standard.
Next: Completely fill the calibration up above the D.O. membrane with the half-value standard.
Remember that this is **Not** an actual calibration. You only record the half-point value in the calibration log.
Next: Allow 3-5 minutes for the reading to stabilize.
Next: Record the half-point value in the calibration log.
LAST: Discard the Conductivity Standard and rinse with deionized water. Do not **ENTER** a calibration value for the half-value Standard. Simply record the reading.

Specific Conductance is now calibrated.

Dissolved Oxygen:
Note: Ensure that the dissolved oxygen membrane is free from bubbles, scratches and deformations. Both D.O. electrolyte and membranes should be changed on a weekly basis. Allow fresh membranes to sit overnight before attempting a calibration. Frequent membrane and electrolyte changes will help ensure accuracy and reduce bio-fouling on the membrane. Calibrate with deionized water that is at room air temperature, so that both the water and the air are very nearly the same temperature. Try to keep the temperature within one or two degrees celsius. This is a very important consideration when calibrating D.O. and should be strictly adhered to. (See Dissolved Oxygen Laboratory Calibration.) **Important:** You should consider a recalibration if the atmospheric pressure exceeds 20 mmHg at the deployment site. It will be necessary because the laboratory or room calibration value might have changed considerably due to a significant increase or decrease in elevation. This is because 20 mmHg corresponds to over 0.2 mg/L change in the value, which exceeds the manufacturer parameter specification accuracy listed for dissolved oxygen. If this is the case recalibrate the D.O. sensor only. (See Dissolved Oxygen Field Calibration.)

Obtaining Barometric Pressure:
Note: Obtain an accurate atmospheric pressure reading from a reputable source. Call your local weather station, look up your local weather page on the internet or purchase a quality barometer. Mercury barometers are very accurate.

FIRST. Determine the elevation at your site. Obtain an accurate vertical control monument that is nearest to the site by locating the nearest USGS monument. Otherwise, look on a USGS quad map. Try to establish your site elevation within approximately fifty vertical feet (50). Example: 4100 feet
Next: Obtain the barometric pressure corrected to sea level for your site. This will already be corrected to sea level for your area. Call the local weather station, look on the internet or purchase a quality barometer.
Next: Convert the barometric pressure corrected to sea level that you obtained in inches of mercury (inHg) to millimeters of mercury (mmHg). Example**:** You obtain 30.11 inches of

mercury from your weather station. Convert this value to millimeters. Now you will do the conversion. Multiply 30.11 by 25.4.

30.11 * 25.4 = *764.79 mmHg*

Next: Adjust the pressure to the elevation at your site. Example: Elevation is 4100 feet. Compute the difference in pressure at your site. In this example because we are 4100 vertical feet above sea level we need to subtract the difference in pressure. Barometric pressure decreases approximately 2.6 mmHg for every 100 vertical feet that is gained. Multiply 0.026 by 4100

0.026 * 4100 = *106.6 mmHg*

Next: Compute the **Actual Local Barometric Pressure** at your site. Example: Subtract the difference in pressure between your site and sea level. 764.79 minus 106.6

764.79 mmHg - 106.6 mmHg = ***658.19 mmHg***

This is the **Actual Local Barometric Pressure value** that you will type and **ENTER** during the D.O. calibration.

LAST: Compute the **Altitude Correction Factor**. Divide your **Actual Local Barometric Pressure (658.19 mmHg)** by the standard barometric pressure at sea level **(760 mmHg)**
Example: 658.19 mmHg divided by 760 mmHg

658.19 / 760 = ***0.8660***

You have successfully obtained the Actual Local Barometric Pressure and the Altitude Correction Factor at your site. Retain both the **Actual Local Barometric Pressure** ***and the*** **Altitude Correction Factor** ***numbers for use later when calibrating D.O for your hydrolab instrument***.

Dissolved Oxygen Laboratory Calibration:

Note: Please see the D.O. computation form.

FIRST: Triple rinse the calibration cup with deionized water.

Next: Slowly fill the calibration cup with deionized water to one-cm below the o-ring and membrane.

Next: Gently dry the membrane with a soft tissue.

Next: Allow the D.O. sensor 5-7 minutes to stabilize.

Next: Record the water temperature.

Next: Record the *Initial D.O. Value* reading from the hydrolab.

Next: Refer to the D.O. SATURATION VALUES Table and locate the recorded water temperature of your hydrolab sensor in the table. (See D.O. SATURATION VALUES Table) Example: ***21.3*** **degrees Celsius** corresponds to a table value which equals ***8.83***

Next: Multiply the corresponding temperature reference value by the **Altitude Correction Factor** that you obtained earlier of **0.8660**

Next: Compute the oxygen concentration value. Example: Multiply **8.83** by **0.8660**

8.83 * 0.8660 = ***7.65 mg/L***

Next: Record the *Computed D.O. Value* in the calibration log.

Next: Press ***(C)alibrate***

Next: Press ***(O)xygen***

Next: Type the *Computed D.O. Value*. Example: Type ***7.65*** mg/L and then Press the ***ENTER*** key.

Next: Allow the D.O. sensor 3-5 minutes to stabilize.

LAST: Record the *Actual D.O. Value* in the calibration log.

Dissolved Oxygen is now calibrated

pH Calibration:

Note: Ensure that the pH buffer solutions have not expired. Select a pH 7 buffer and another buffer that is close to the value of your sampling site. Ensure that electrolyte is changed on a weekly basis. If equipped with a LISREF sensor be sure to keep the protective cap filled with electrolyte when not in use. Select a pH sensor that will accurately sample the water at the sampling site. Generally water that is less than approximately 150 ms/cm should be sampled with the hydrolab LISREF pH sensor. Use the Standard Reference pH sensor to sample water that is greater than this value. When ordering your pH sensor purchase the proper sensor.

FIRST: Triple rinse the sensors with distilled water.
Next: Prerinse with the 7.00 buffer.
Next: Slowly fill the calibration cup above the D.O. membrane. Be careful to prevent bubbles.
Next: Allow the pH sensor 3-5 minutes to stabilize.
Next: Record the *Initial Value* in the calibration log.
Next: Select ***(C)alibrate***
Next: Select ***(p)H***
Next: Record the temperature of the pH 7 buffer solution.
Next: Refer to the buffer solution container or a pH Standard Table and find the value of the buffer at the recorded temperature.
Next: Record this as the *Chart Value* in the calibration log. Example: pH 7 buffer at 20 degrees Celsius is equal to a *Chart Value* of 7.02 pH units.
Next: Type ***7.02*** and then press the ***ENTER*** key.
Next: Allow the reading 3-5 minutes to stabilize.
Next: Record the *Actual Value* in the calibration log.
Next: Discard the pH 7.02 buffer and then rinse with deionized water.
Next: Rinse with deionized water again.
Next: Prerinse with pH 10 buffer. Example: Upper Klamath Lake is near 10.00 pH units.
Next: Slowly fill the calibration cup above the D.O. membrane. Be careful to prevent bubbles.
Next: Allow the pH sensor 3-5 minutes to stabilize.
Next: Record the *Initial Value* in the calibration log.
Next: Select ***(C)alibrate***
Next: Select ***(p)H***
Next: Record the temperature of the pH 10 buffer solution.
Next: Refer to the buffer solution container or a pH Standard Table and find the value of the buffer at the recorded temperature.

Next: Record this as the *Chart Value* in the calibration log. Example: pH 10 buffer at 20 degrees Celsius is equal to a *Chart Value* of 10.05 pH units.
Next: Type ***10.05*** and then press the ***ENTER*** key.
Next: Allow the reading 3-5 minutes to stabilize.
Next: Record the *Actual Value* in the calibration log.
LAST: Discard the pH 10.05 buffer and then rinse with deionized water.

pH is now calibrated.

ORP (Redox) Calibration:

Note: Calibrate ORP at least once a month. Calibrate ORP with Zobell=s Redox Solution Theoretical Potential. Ensure that the calibration Solution has not expired. The units expressed for Redox are expressed in milliVolts (mV).

FIRST: Triple rinse with deionized water.
Next: Prerinse the sensors with Zobell=s Redox Solution.
Next: Slowly fill the calibration cup above the membrane
Next: Allow the reading to stabilize.
Next: Record the *Initial Value* in the calibration log.
Next: Record the *Chart Value* in the calibration log.
Next: Select **(C)alibrate**
Next: Select **(R)edox**
Next: Type ***229 mV*** and then press the ***ENTER*** key.
Next: Record the *Actual Value* in the calibration log.
LAST: Triple rinse with deionized water.

Dissolved Oxygen Field Calibration:

Note: Professionals engaged in collecting water quality data should consider doing a recalibration for D.O. only if the deployment site is 20 mmHg greater than the laboratory or office calibration site. If you are deploying instruments at relatively higher or lower elevations of approximately 750 feet in elevation difference you should probably reconsider doing a D.O. calibration. Barometric pressure greater than 20 mmHg corresponds to a 0.2 mg/L change in the D.O. concentration value which can equal or exceed the manufacturer=s specification listed for accuracy. Bring along a gallon of deionized water if you will need to recalibrate.

FIRST: Obtain the **Actual Local Barometric Pressure.**
(See **Obtaining Barometric pressure)**
Next: Obtain the **Altitude Correction Factor**. (See **Obtaining Barometric Pressure)**
Next: Proceed in the same manner as the **Dissolved Oxygen Laboratory Calibration.**
LAST: Record the values in your yellow field notebook and make notes accordingly.

Post Calibration Check:

Note: The post calibration check is not an actual calibration. It is simply a procedure to record information pertinent to the instrument. The information provided by the post calibration check can be used to help professionals realize approximate drift values and deployment logging intervals. As a result, professionals may increase or decrease the logging intervals to obtain the best possible accuracy. Most importantly, it serves as a good measure of performance.

Specific Conductance Post Calibration Check:

FIRST: Rinse with deionized water.

Next: Completely fill the calibration cup above the D.O. membrane with the Conductivity Standard used to calibrate the instrument. Example: Check with the 147 µS/cm standard. Do **Not** check against the half-Value standard. Pour slowly to prevent bubbles from forming on the sensors.
Next: Allow the Conductivity sensor 3-5 minutes to stabilize.
Next: Record the post calibration check value in the calibration log.
LAST: Discard the Conductivity Standard and rinse with deionized water.

Dissolved Oxygen Post Calibration Check:

FIRST: Rinse with deionized water.
Next: Gently dry the membrane with a soft tissue.
Next: Allow the D.O. sensor 5-7 minutes to stabilize
Next: Record the water temperature.
Next: Refer to the D.O. SATURATION VALUES Table and locate the recorded water temperature of your hydrolab sensor in the table. (See D.O. SATURATION VALUES Table) Example: ***21.3*** **degrees Celsius** corresponds to a table value which equals ***8.83***
Next: Multiply the corresponding temperature reference value by the **Altitude Correction Factor** that you obtained earlier of **0.8660**
Next: Compute the oxygen concentration value. Example: Multiply **8.83** by **0.8660**
8.83 * 0.8660 = ***7.65 mg/L***
Next: Record the *Computed D.O. Value* in the calibration log.
LAST: Record the *Actual D.O. Value* in the calibration log.

pH Post Calibration Check:

FIRST: Rinse the sensors with distilled water.
Next: Slowly fill the calibration cup above the D.O. membrane with pH 10 buffer.
Next: Allow the pH sensor 3-5 minutes to stabilize.
Next: Record the temperature of the pH 10 buffer solution.
Next: Refer to the buffer solution container or a pH Standard Table and find the value of the buffer at the recorded temperature.
Next: Record this as the *Chart Value* in the calibration log. Example: pH 10 buffer at 20 degrees Celsius is equal to a *Chart Value* of 10.05 pH units.
Next: Record the *Actual Value* in the calibration log.
LAST: Discard the pH 10.05 buffer and then rinse with deionized water.

ORP Post Calibration Check:

FIRST: Rinse the sensors with distilled water.
Next: Slowly fill the calibration cup above the D.O. membrane with Zobell=s Redox Solution.
Next: Allow the ORP sensor 3-5 minutes to stabilize.
Next: Record the *Chart Value* in the calibration log.
Next: Record the *Actual Value* in the calibration log.
LAST: Triple rinse the sensors with deionized water.

KBAO Disclaimer:

The data included within contains the following provisions: The data is unadjusted raw data as collected by the Bureau of Reclamation Klamath Basin Area Office. Data has been edited only to remove bias data that was captured due to both early and late deployment and retrieval times. Some of the possible factors affecting data quality include, but are not limited to the following: Calibration, maintenance, length of deployment, presence of biological organisms and sensor failure. Calibrations primarily include: *Specific Conductance, Dissolved Oxygen, pH and Redox.*

Bureau of Reclamation
Klamath Basin Area Office
Klamath Falls, Oregon

Calibration Log

Proceed from left to right top to bottom.

Unit Serial Number: __________ Unit Type: __________
Calibration Date: __________ Technician: __________
Post Cal. Check Date: __________ Log Site/Logging Interval __________

Parameters:	Range µs/cm	Calibration Points µs/cm	Calibration Values µs/cm	Linearity Points µs/cm (Half-Value Standard)	Post Calibration Check µs/cm
Specific Conductivity (1 Point Calibration)	0→150 150→1500 1500→10000	147 ________ ________	Initial Value ______ Standard Value ______ Actual Value ______	74	________

DO (1 Point Calibration)						
Refer To The D.O. SATURATION Values Table When Computing D.O. Concentration Values			Air: °C Water: °C	Altitude: Feet Barometer: mmHg		
			Post Cal Air: °C Post Cal Water: °C	Post Cal Altitude: Feet Post Cal Barometer: mmHg		
Membrane	Method	Initial Value	Computed D.O. Value	Actual Value	Post Calibration Check: Computed	Actual
Standard	mg/L %SAT	mg/L %SAT	mg/L %SAT	mg/L %SAT		
Low Flow	mg/L %SAT	mg/L %SAT	mg/L %SAT	mg/L %SAT		

DO (1 Point Calibration At Site If Necessary)						
Refer To The D.O. SATURATION Values Table When Computing D.O. Concentration Values			Air: °C Water: °C	Altitude: Feet Barometer: mmHg		
			Post Cal Air: °C Post Cal Water: °C	Post Cal Altitude: Feet Post Cal Barometer: mmHg		
Membrane	Method	Initial Value	Computed D.O. Value	Actual Value	Post Calibration Check: Computed	Actual
Standard	mg/L %SAT	mg/L %SAT	mg/L %SAT	mg/L %SAT		
Low Flow	mg/L %SAT	mg/L %SAT	mg/L %SAT	mg/L %SAT		

pH (2 Point Calibration)	7-10	7 ___°C	Initial Value: ________ Chart Value: ________ Actual Value: ________	10 ____°C	Initial Value: ________ Chart Value: ________ Actual Value: ________	Post Calibration Check Temperature °C Chart Value _______ Actual Value _______

ORP (1 Point Calibration)	Redox Solution	Zobell's Redox Solution Theoretical Potential in mV	Post Calibration Check With Zobell 's Redox Solution + 429 mV
	Temperature_______°C	Initial Value _______ mV Chart Value _______ mV Actual Value _______ mV	Chart Value __________ mV Actual Value __________ mV

Temperature	Certified N.I.S.T. Precision Thermometer _______ °C Instrument Temperature Reading _______ °C

Notes:

- Before starting the calibration, remember to check the maintenance log. The unit should be maintained before calibration.
- Make sure that all data in the unit's memory is backed up properly and safely before proceeding with the maintenance or logging setup.

Field Deployment Protocol

Required Supplies

- pH Reference electrolyte
- Datasonde sensor guard (if replacing a Datasonde unit, use the sensor guard from the unit being replaced)
- Keys to unlock Datasonde protective casing
- Keys for access to deployment locations (e.g., Shasta River)
- Marine lubricant/anti-corrosion spray
- Bound field notebook
- Waterproof pen (e.g., Sharpie)
- Field data sheets (and clipboard)
- Camera and film
- A copy of the Datasonde deployment protocol

Procedures

Office

- Review field equipment list
- Obtain a recently calibrated Hydrolab Datasonde unit. This will be delivered by a courier service or by Bureau of Reclamation (BOR) personnel.

Field (repeated at each deployment site)

Prior to Removing Deployed Probe

- At the deployment site, record the time and any environmental and/or site conditions in the logbook (e.g., precipitation, river turbidity).
- Record "new/ingoing" probe number in the logbook and note probe condition.
- Record existing in-stream condition of "old" (to be retrieved) probe – conditions as they are when you arrive at the site (e.g., "The Hydrolab Datasonde protective casing was out of the water and on the riverbank. The casing was completely dry and looked like it had been out of the water for some time. There is no observable damage to the probes" OR " The casing was buried in sediment").
- At a minimum monthly photographs are required at each site to monitor conditions.
- If necessary (and possible) photograph conditions at the site to further document changes. Photographs can be used to document any conditions found at the site (e.g., probe, locks, cables, river, casing, etc.). In all cases note photograph number on data sheet for future cross-reference.

Probe Removal and Re-deployment

- Remove the deployed Datasonde protective casing from the river. Note anything that looks unusual or suspicious.
- Remove the lock on the Datasondeprotective casing, **only** after the casing has been taken to a level or secure location away from the riverbank. This is to reduce the risk of the unlocked Datasonde casing from falling/sliding into the river. If the lock is difficult to open or if there is corrosion present, spray the lock with marine lubricant/anti-corrosion spray.

- Remove the “old/retrieved” Datasonde unit (the unit being replaced) from the protective casing. Carefully inspect the probe and casing assembly: note probe condition and/or anything that looks unusual or suspicious.
- Remove the sensor guard from the “old/retrieved” Datasonde unit. **Caution!** The probes are now completely exposed and are at the greatest risk of being damaged. Set the unit on its side in a secure location (e.g., place the probe out of harms way from “new” probe deployment work and do not allow it to roll/slide, possibly damaging the probe).
- Remove the storage cup from the “new/ingoing” Datasonde unit (the unit just received from the courier service or from BOR personnel). Set the storage cup on the ground.
- Remove the black pH reference cap from the “new/ingoing” Datasonde unit. Set the “new/ingoing” Datasonde unit on its side in a secure place.
- Place the black pH reference cap onto the “old/retrieved” Datasonde unit, *make sure the pH reference cap is full of pH electrolyte*.
- Place the storage cup full of water onto the “old/retrieved” Datasonde unit. Set the unit on its side in a secure place.
- Carefully place the sensor guard onto the “new” Datasonde unit. When putting the sensor guard on a unit be aware of the glass probes. They are fragile and can break from a light impact with the sensor guard.
- Gently slide the “new” Datasonde unit with the sensor guard into the protective casing, close the case, and replace the lock.
- Carefully deploy the “new” Datasonde unit and protective casing into the river. The objective is to place the probe in a well-mixed area, most representative of mainstem conditions. Look for objects and undesirable substrate conditions **before** you deploy the unit in the water. That is,
    - Avoid large rocks that may damage the instrument during deployment
    - Avoid submerged logs/debris where the probe could get snagged
    - Avoid deposits of fine sediment
    - Avoid slow backwater areas, side channels, and other areas not representative of mainstem conditions

Record the “old/retrieved” Datasonde number on the field sheet
Record the “new/ingoing” deployment condition prior to leaving site (under “Comments/Remarks”):

- distance from shore
- depth
- estimated velocity
- substrate condition
- riparian vegetation
- etc.

Post-Field Review

- Review logbooks for completeness. Do not hesitate to utilize extra pages in the logbook if necessary. Do not skip pages.
- Review field notes and notify USBR- Klamath Falls of potentially important findings (e.g., probe condition, vandalism, major changes in environmental conditions at site that may affect sampling).
- After each deployment copy logbook entries and send copies to USBR-Klamath Falls.
- Review available materials and supplies and notify USBR-Klamath Falls if additional materials and supplies are required.

APPENDIX E: TEMPERATURE MONITORING PROTOCOL

Water temperature monitoring provides information for multiple purposes. The quality, frequency, format, and accessibility of temperature data is important to effective application of scientific methods to studies of biological, ecological, and water quality conditions in the system. Outlined herein are the protocols for water temperature monitoring.

Objective

Monitor water temperatures in river systems to more completely define the thermal regime over space and time. Sufficient detail is required to capture diurnal changes in mainstem water temperature, to determine seasonal changes in thermal regime, to monitor season-to-season changes in water temperatures.

Equipment

To fulfill the objective of the monitoring program, remote logging thermistors are deployed to record time series of temperatures at various locations in the river. Such logging thermistors ("loggers") can record information at various, user-specified intervals and can be deployed for long periods of time.

Onset Stowaways® temperature devices in waterproof cases are employed. These devices are economical, have a high reliability and an acceptable accuracy (±0.2°C or ±0.4°F). The response time in water is sufficient (less than 15 minutes) for hourly measurements. If other logger brands/types are used they should have a similar accuracy and response time.

Equipment Protocol

New Loggers: all new loggers are inventoried, by serial number. The logger number, date of purchase, attributes (memory size, battery life, etc.) are included. Equipment should be properly labeled. Using permanent marker write the logger serial number on the inside and outside of the cannister, include the date for battery replacement purposes.

New Loggers: all new loggers are tested prior to field deployment to assure they function properly.

Existing Loggers: each year the logger inventory is examined to determine if:

a) a logger needs to be replaced (e.g., replacing a out of date logger, or a logger is lost/fails),
b) if the battery replacement is required (write month and year on battery),
c) if equipment needs to be maintained (frayed cord, degraded case, degrade "O" ring, properly lubricated "O" ring, relabeled case, cracked case, etc.).

Deployment Design

Deployment includes defining the deployment locations, recording season, recording interval, download frequency, and maintaining a deployment log.

Deployment Locations

Deployment locations should be the same year-to-year to provide a consistent representation of the river. This does not imply inflexibility, but it should be a goal. Also, there may be sites that hold special interest for select studies or for short-term requirements that can be monitored as needed. Locations may be monitored year-round or seasonal. Locations may be prioritized in terms of importance when making monitoring decisions.

For this study, temperature loggers are deployed at:
1) Klamath River above Cottonwood Creek (RM 182)
2) Klamath River above Shasta River (RM 176.7)
3) Klamath River at Walker Road Bridge (RM 156)
4) Klamath River above Scott River (RM 143.5)
5) Scott River (RM 1.0)

Recording Season
In order to ensure successful retrieval of devices special care must be used during winter months. Deployment and retrieval are functions of weather and runoff conditions and staff availability. Safety is always the first priority.

For this study the deployment season ranges from April into November, 2000.

Recording Interval
To effectively record daily maximum and minimum temperatures and to represent the diurnal cycle data is recorded hourly and on the hour. For ease of data manipulation and presentation, as well as data comparison all loggers should be programmed to start at a fixed time – e.g., midnight. "Trigger starting in the field should be avoided if necessary. <u>It is vital to ensure that the time on the computer is correct when launching loggers</u>!

For this project the deployment interval is 1 hour.

Download Frequency
Download frequency is often governed by budget and time constraints. For practical reasons, download frequency is on the once per quarter (approximately 3 month intervals). This time frame allows flexibility in planning, while minimizing the risk of lost data – a loss of a few months of data is better than losing an entire year. Certain loggers may have a higher priority for download to minimize loss of data. Other download frequencies can be selected depending on available personnel. The selected loggers (with 8Kb of memory) will record for over 300 days at 1-hour intervals. This allows some flexibility during the winter season when access to loggers may be difficult, but quarterly downloads should be maintained to the extent possible.

For this study the download frequency is roughly 2 months.

Deployment Log
The deployment log is a running record of loggers. Should include, but is not limited to

- Logger serial number,
- Date of deployment,
- Location of deployment (general),
- Time of deployment,
- Recording interval,
- Approximate depth,
- Estimate of water velocity (should not be standing water)
- Distance from bank (right and left bank designations are made looking in the downstream direction),

- Memory available (e.g., how many days can it be left in the field: assume 300 days for loggers with 8Kb of memory),
- Download filename,
- Complete physical description of deployment site, benchmarking with a tape measure to a well described object if necessary, and if possible photographs,
- Condition of the logger,
- Flow conditions or changes in flow,
- If photographs are taken, note number of photo in camera (occasional photo-documentation is valuable)
- Any conditions which may affect the temperature record.

On occasion, the deployment log should be photocopied to provide a backup in case the log is lost. A sample data sheet is shown in Table E-1.

Table E-1 Sample temperature monitoring data sheet

Water Temperature Monitoring
Date: ___________ Field Personnel: ____________________
Time: ___________ ____________________

Location	Time:	Logger # Removed	Logger # Deployed	Tw	Tair	Approx. Depth (ft)	Distance fr. bank (ft)	Velocity >1 ft/sec (Y/N)	Condition @ Retrieval	Changes in Re-deployment
Download filename:										
Download filename:										
Download filename:										
Download filename:										

Field Notes

Field Deployment Protocol

Field deployment protocol includes where to deploy the logger and field downloading procedures.

<u>Logger Deployment</u>

Loggers should be deployed in areas that are representative of main-stem temperatures. If loggers are deployed for other reasons (e.g., stratification in impoundments/deep pools, influence of return flows, backwaters) those reasons should be clearly stated in the deployment log. Careful placement is required in locations where water level fluctuations may affect temperature readings should flows significantly decrease. If a logger is moved for any reason (e.g., flow change) it should be noted in the deployment log. Personnel deploying equipment should always be denoted in the log.

Loggers are deployed in protective iron pipe containers, attached to the bank with braided stainless steel cable. The cable may be attached to a natural structure or to framing stakes driven into the bank. Framing stakes should be driven in to full depth if possible and should be placed out of harms way. Cable lengths vary, but are typically 10 to 15 feet in length. Often less cable is required. In such a case carefully coil the cable on the bank – do not leave excess cable in the river. Rarely will more cable be required. Attaching two cables together for a deployment more distant from the bank is discouraged.

Safety is always a paramount issue. Loggers should not be located in areas where there is risk to life or limb. Conditions may change throughout the year, what once was a benign riffle may be dangerous at high flows. Likewise, landowner permission is a pre-requisite prior to deployment. *If conditions are deemed unsafe do not attempt to deploy or retrieve a logger. Always err on the side of caution.*

Logger Downloading

In the field, loggers are downloaded using a laptop computer (PC). Supplies include a well-charged battery for the PC, appropriate cables to link the logger to the PC, diskettes to save files if necessary, appropriate equipment to retrieve and access the logger (wrenches, channel locks) and the deployment log. Downloaded files should be saved to the computer and the filenames noted in the deployment log. If a logger is replaced (i.e., lost logger) the new number should be denoted in the record. The person performing the download should include their name in the log.

Field Quality Control

If desired, temperature loggers can be checked against calibration thermometers in the field. This step may not be required if the loggers were properly tested prior to deployment. It is time intensive, requiring a separate trip to all locations to measure water temperature. It has been found that the selected devices (ONSET Stowaways) have been highly reliable. If a location is of special concern, this measure can be taken. No special measures were taken for this study.

Removal of Field Deployment Equipment

At the termination of the fieldwork, all materials will be removed from the field. No debris should be discarded in the field.

Data Management

Data management consists of transferring downloaded files to the PC and to diskette for backup, examination of the data, and updating the data inventory.

Data Transfer and Backup

Once the data is retrieved from the loggers, all raw data files are downloaded to the PC diskette. This is the master data set – the original data from the field. Presumably, all analyses using the data can be re-created from these data sets. The diskettes should be properly labeled and stored. PC files should be well organized with a "table of contents" file defining how and where all files are stored.

A copy of the files should be sent to the appropriate personnel and agencies to ensure timely review of the data.

For this project he data will be compiled in electronic format and supplied to the US Bureau of Reclamation – Klamath Area Office.

Examination of Data

Once the data is downloaded, the data should be examined to determine if the record is reliable. The most direct method is to plot the data and critically examine the water temperature trace. Common problems include

- logger failure (PC can't find the logger file),
- thermistor failure (negative temperatures),
- improper launching of the logger (no data),
- exposure to air (excessive temperatures),
- not in mainstem (increased temperature – usually associated with a flow change)
- affected by local conditions (e.g., filling to draining of an impoundment).

It is helpful to review the data in concert with available flow and air temperature information. It is also useful to compare loggers to determine if a particular logger is not in agreement with nearby loggers.

Updating Data Inventory

The data inventory defines all of the temperature data, filenames, record starting and ending dates, missing data, logger failures/losses. Further, the data included herein are different than the "raw" field data because they have been reviewed for completeness, erroneous temperatures have been deleted (e.g., air temperatures prior to deployment), and the data set has been documented as representative of water temperature in the system. It is paramount that this file be maintained, as it is the basis of the data management system.

Data Interpretation

Data use and interpretation is the ultimate goal of the water temperature monitoring program. There is potential for a wide variety of application of temperature data. There is uncertainty associated with all data, which should be taken into account during interpretation. Uncertainty may include logger accuracy, placement of loggers, correct time of measurements, and human error. By using reliable equipment, testing devices prior to deployment, predetermined deployment and downloading protocols, maintaining a complete and accurate deployment log, archiving raw data, and keeping an up-to-date data inventory, such errors can be minimized, or at least their magnitude documented. The result is that data can be applied to monitoring programs and scientific studies with a greater degree of confidence.

Summary of River Water Temperature Monitoring

Field Equipment

- 8K Stowaway Loggers and waterproof cases (or appropriate loggers): Record serial #s on interior and exterior of cases with permanent pen. (Spare loggers should not be deployed for purposes other than those defined in the study.)
- "O" ring lubricant

- Boxcar Software (to launch and download)
- replacement batteries

Field Equipment Checklist

<u>Caution: do not work at waters edge except as necessary to remove and deploy equipment. To reduce loss of equipment and for safety concerns move back from the stream to complete field work</u>

- PC laptop (with charged battery and power cord (AC power may be available in the field at certain locations, e.g., campground))
- Logger download cable
- Log book or log sheets
- Permanent pens/markers (spare)
- Maps
- Photo album showing deployment locations (so you can find the place again)
- Camera with spare film
- Spare loggers
- Spare canisters with appropriate bolts
- Spare cables and hardware (Shackles, sleeves, ferrules, etc.)
- Spare form stakes
- Zip ties
- Mallet
- Wrenches to open canisters: suggest two crescent wrenches in case bolts/nuts are variable size
- Cutters to cut zip tie
- Channel locks to open the logger
- Spare "O" ring lubricant
- Rags – plenty of them
- First aid kit
- It is helpful to bring along other tools: Screwdrivers, pliers, knife, etc.

Locations

List of Locations (See above)

Frequency

Note frequency: "Data will be recorded at _____ (e.g., hourly) intervals."

Schedule

The deployment schedule is designed with variable flow conditions in mind. The deployment, download and retrieval schedule includes field dates and locations. The schedule is meant to provide guidance and should be adapted to changing conditions, as it is almost certain that changes will be required to effectively monitor water temperature. Large flows, low flows, sudden flow changes, or other unforeseen circumstances may warrant trips to the field to check, move, and or replace loggers.

Deploy: Date (MM/DD/YY): __________
Download #1: Date (MM/DD/YY): __________
Download #2: Date (MM/DD/YY): __________
Download #3: Date (MM/DD/YY): __________
.
.

Download #n:	Date (MM/DD/YY): __________
Retrieve:	Date (MM/DD/YY): __________

APPENDIX F: BENTHIC ALGAE SAMPLING

Objective

Determine bulk primary production growth rates for the Klamath River below Iron Gate Dam for use in numerical models

Locations

Benthic algae are sampled at two locations in the Klamath River below Iron Gate Dam:
1) Below Iron Gate Dam (RM 190)
2) Above Cottonwood Creek (RM 182)

These locations have approximately the same aspect and stream velocities and depths during the late spring through summer periods.

Frequency

There are two sampling series during the 2000 season occurring in late-May, late-July, and early-September. Deployments will consist of weekly samples for a period of 3 to 6 weeks depending on rate of growth.

General Method

Two methods are employed to assess algal growth in the Klamath River. The first method is strictly qualitative observation. Artificial substrate consisting of 6 inch square, unglazed ceramic tiles attached to 8 inch by 18 inch cinder blocks are assessed at weekly intervals and their condition described in a narrative. Two tiles occupy each block. The tiles are photographed to provide visual documentation of changes through the sampling period. These qualitative observations provide insight on colonization, variations in algal assemblages, impacts of grazing, spatial variability, and general seasonal changes. No lab work is associated with this task.

The second method also utilizes artificial substrate. Periphyton samplers consisting of a floating slide rack and glass microscope slides are employed. Three samplers are deployed at each site (24 total slides). All samplers are placed, exposed, and handled in nearly as identical fashion as possible. The exposure period is 3 to 6 weeks during all sampling events. Four samples are collected for each sampling event and location. Ideally, samples are collected at weekly intervals, but if conditions are such that growth is sparse or excessive, sampling periods may be varied. However, the total number of samples be collected shall not be less than three nor more than five.

<u>Deployment</u>

Deployment for sampling studies shall take place in waters between 2 and 3 feet deep where velocities are between 1 and 3 feet per second. All samplers are placed within the same geomorphic channel unit (e.g., run, riffle or pool). Deployment of artificial substrate differs for the ceramic tiles and glass slides.

Ceramic Tiles

Tiles are deployed in the river a minimum of two weeks prior to initial sampling to allow tiles to saturate and, to some degree, become colonized with algae. Substrate remains in the river between sampling series. It is important to maintain depth and velocity considerations during these non-sampling periods, but not critical. Tiles shall not deployed in areas subject to sedimentation, desiccating, and excessive shading. Prior to sampling event all tiles are scrubbed clean with a nylon brush. The cinder block is cleaned as well to minimize fouling from adjacent benthic algae.

Six to twelve tiles are deployed at each location (3 to 6 cinder blocks). Blocks may be moved during sampling events if they have shifted (e.g., turned over) or flow changes have changed conditions sufficiently to warrant re-deployment consistent with the depth and velocity criteria. Locations where riparian or topographic shading is appreciable are avoided. All tiles are cleaned prior to the sampling deployment as noted above in substrate preparation. To the extent possible tiles are deployed at approximately equal depths and equal stream velocities. Tiles are deployed, if possible, with their long axis normal to the principal flow direction. Document the initial position of each tile and changes that occur during the sampling event. Sampling locations are coincident with the floating periphyton samplers.

If possible, a temporary staff gage, consisting of a wooden stake near the river's margin, is set up to compare relative variations in stage through out each sampling period. At the site below Iron Gate Dam changes in stage can be estimated from the USGS gage located approximately 200 yards downstream of the sampling site. All sites are photographed during each visit. A deployment field sheet is included below. One sheet is used for each site.

If tiles have moved, are missing, damaged or if conditions have changed, redeployment may be necessary. Redeployment should occur locally and similar conditions maintained. If redeployment is necessary, the appropriate documentation in the field data sheets must be completed. Photographs should be taken to document conditions.

Tiles shall <u>not</u> be re-deployed if water clarity changes. Further, site conditions are assessed during each visit to ensure that neither riparian vegetation (e.g., grasses, shrubs) nor adjacent benthic algae have grown to the extent to impair growth on the artificial substrate. It may be necessary to periodically clean benthic algae from the cinder block.

Floating Periphyton Samplers

Artificial substrate for the floating periphyton sampler consists of a floating rack containing glass microscope slides. Slides are cleaned with a damp cloth followed by rinsing 3 times with deionized (DI) water. Clean slides prior to deployment in rack. Ensure no debris or other foreign matter is in rack or on slides. Number each sampler as per site location as well as the sampler slide rack (i.e., number slide rack slots sequentially 1 through 8).

Three samplers are deployed at each location. Each sampler is anchored to the bottom with cable or nylon rope. All samplers are placed in as near as equivalent conditions as possible. Floating samplers and ceramic tiles are placed in the coincident locations. Document and photograph all deployments.

If samplers have moved, been vandalized, or flow conditions have changed, it may be necessary to move the device. All attempts should be made to maintain conditions outlined above. Document changes and photograph prior to and after re-deployment.

Field Sampling

Sampling procedures are as follows:

Ceramic Tiles

1) At each site the tiles are examined in situ. Record any observable characteristics prior to removing from stream. Note variability, any benthic fauna, if adjacent natural or artificial substrates are "interfering" with the artificial substrate. Photograph if possible.
2) Retrieve cinder block containing representative tiles.
   a) Use caution not to disturb the benthic algae on the tiles or cinder block.
   b) Note condition of tile: broken, obvious grazing (presence of grazers), debris attached, sediment, etc.
3) Photograph the tiles, noting photograph number, include a sketch (with referenced photo #) and provide a brief narrative describing
   - Sampling site,
   - Sampling date
   - Personnel
   - Conditions (weather, flow)
   - Depth of substrate
   - Approximate water velocity (if a flow meter is available determine velocity at 0.6D and 10 cm above bottom)
   - Condition of substrate (amount of growth, variability, color, etc)
   - Grazing
   - Other benthic fauna

   It may be useful to place the tiles in a few inches of water to more clearly see the condition of the substrate. Take previous field logs and photographs on each trip to more completely assess changes in algae status. *Consistency and completeness is critical to the narrative/description.*
4) Do not remove and flora or fauna from the substrate.
5) Replace the substrate with as little disturbance as possible. If there is substantial debris or sediment on tile or block gently remove (by hand) and/or wash.

Floating Periphyton Sampler: Glass Slides

Slides are collected and placed intact in high density polyethylene (HDPE) bottles. Bottles are washed 3 times with deionized water (swirl sufficiently with cap on and discard – repeat). Bottles and caps are allowed to air dry (prepare prior to going into field). All bottles are wrapped with aluminum foil immediately upon sample collection.

Chlorophyll a: slides are placed in HDPE described above. Label bottles appropriately for chlorophyll a analysis. Label bottles appropriately for chlorophyll a analysis. Wrap bottles in aluminum foil. Place on dry ice and transport to the laboratory.

Dry and Ash Free Weight (AFDW): slides are placed in HDPE described above. Label bottles appropriately for dry and ash-free weight. Fill in all appropriate label information. Wrap bottles in aluminum foil. Place on dry ice and transport to the laboratory.

At each of the two sampling locations four slides are collected:

- One slide for chlorophyll a and (one bottle – one slide per bottle)
- Three slides for AFDW (triplicate: three bottles – one slide per bottle)

The slides to be removed will be determined prior to going to the field. Retrieve the sampler from the river and process (remove) samples at the shoreline to reduce risk of lost slides/samples. To ensure consistent deployment location, leave anchor in river and retrieve only the sampler. Remove excessive algae attached to the sampler and process slide in clean plastic tub. If material is accidentally scraped/lost from slide recover as possible from the tub and placed in the sample bottle. (Use a clean razor blade to retrieve algae biomass from tub.)

Once a slide is removed from the floating rack, a new slide is deployed in the slot. This new slide is only to ensure consistent flow conditions within the floating sampler assembly and will not employed as an artificial substrate sample location.

Check rack to ensure slide carriage is properly engaged (to avoid loss of slides), inspect sampler for damage, and return rack to river. Make sure rack is placed with shield facing upstream; clean excessive benthic algae growth from anchor line.

Laboratory Procedures

<u>Chlorophyll a</u> (Standard Methods: 19th Ed. 1995, 10200 H, 10300 C))
1) Remove material from both faces of the slide with razor blade or rubber policeman
2) See Standard Methods: 19th Ed. 1995, 10200 H.

<u>Dry and Ash-Free Weight</u> (Standard Methods: 19th Ed. 1995, 10300C)
1) Remove material from both faces of the slide with razor blade or rubber policeman. *Do not process on slides unless high temperature slides are used and specifically noted on sample collection bottles.*
2) See Standard Methods: 19th Ed. 1995, 10300 C.5. **<u>NOTE</u>**: *Do not process on slides unless high temperature slides are used and specifically noted on sample collection bottles. If in doubt remove material and process in crucible.*
3) Report dry and ash-free weights per area of sampled surface.

Shipping and Handling

<u>Dry Ice</u>

All samples are to be placed on dry ice. Each container should include only a microscope slide and minimal water. Dry ice shipments will arrive on Tuesday or Wednesday of the appropriate week. The shipments should have sufficient dry ice (if not disturbed) to accommodate Wednesday sampling and Wednesday shipping to the Redding Laboratory. Do not handle dry ice. The container should be opened and samples placed within and immediately sealed. There should be little or no reason to "repackage" the contents, e.g., dry ice.

<u>Field Data Sheets, Field Log Sheets, and Chain of Custody</u>

Field data sheets and field log sheets should be filled out completely by field personnel. Prior to shipping, information from the field log sheet is transferred to the chain of custody (COC) forms. Copies are made of all documents and the originals sent to:

US Bureau of Reclamation – Regional Office
Attn: Victor Stokmanis
2800 Cottage Way
Sacramento CA, 95825

Shipping

Include the COC in a plastic bag inside the container. Package securely and send to

Basic Laboratory
2218 Railroad Avenue
Redding CA 96001

Retain the pink copy of the COC.

Field Equipment

- Floating periphyton samplers (7), properly labeled with clean slides
- Spare slides
- Anchor cable/rope
- Split rings
- Anchors
- Pre-cleaned bottles for sample slides
- Deionized water (squirt bottle)
- Ceramic tile/Cinder blocks (in river)
- Field book/data sheets
- Permanent pens
- Camera and film
- Polaroid camera and film
- Plastic tub
- Razor blades
- Waders
- Current meter (flow and depth)
- Thermometer
- Dry ice
- Small ice chest
- Duct Tape (to seal ice chests)
- Protocol
- Shipping forms
- Chain of custody forms (and plastic bag for shipping)
- Field log

Attachments: Field Data Sheets, Labels, and Field Log

Attached Algae Survey: Field Sampling Sheet

Site Information	
Site Name:	Date: (MM/DD/YY)
Site Identification Number:	
Sampling Team:	Time:

Deployment Status

Sampler and Tile Deployment (two tiles per block)	Sampler ID #	Number of Blocks	Blocks Cleaned (circle)	Depth (2 to 3 ft) (ft)	Velocity (1 to 3 fps) (fps)	Distance from Bank (ft)
Sampler 1			Y N			
Sampler 2			Y N			
Sampler 3			Y N			

Substrate Condition

Photograph Site	
1. Across Stream	Y N
2. Downstream	Y N
3. Stream Bed	Y N
4. Tile - subsurface	Y N
5. Other: ________________	Y N
6. Other:	Y N

Field Conditions

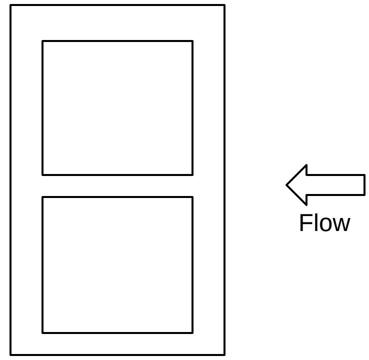
Clouds (%):	Wind:		Precipitation:	
Other conditions:				
Stream Stage (from datum) (ft):	Velocity (fps):			
Water temperature (C):	Other: (e.g., DO, pH, etc.)			
Water clarity (circle): very turbid	turbid		slightly turbid	clear
Riparian shading (circle):	exposed	partially shaded	shade	
Topographic shading (circle):	appreciable	moderate	small	

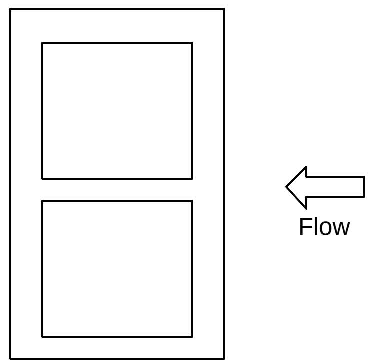
Remarks

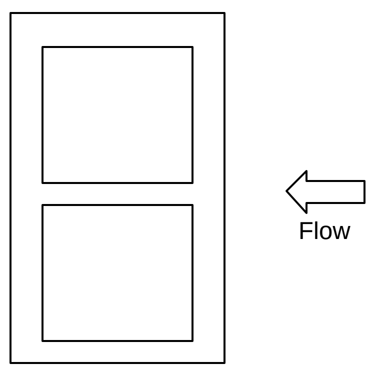
Sheet 1 of 3

Sampling Information: Ceramic Tiles Narrative

When using schematics, please label and refer to figures appropriately





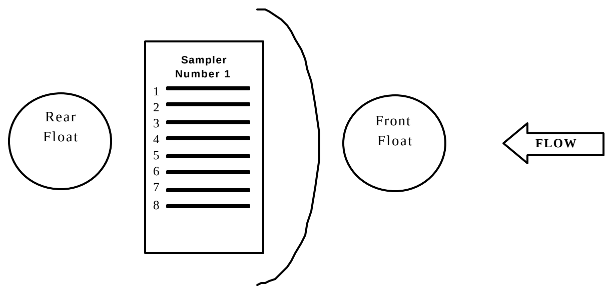


Sheet 2 of 3

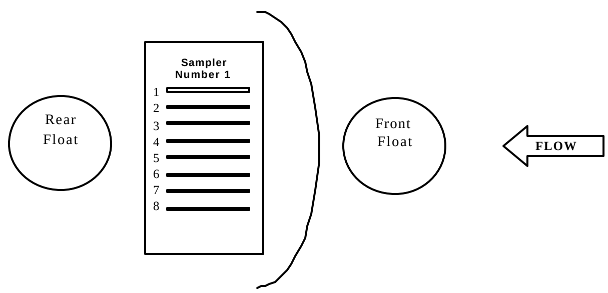
Floating Sampler Collection: Microscope Slides

For each sampler denote which slides were collected for Chlorophyll a and AFDW on the appropriate schematics. Provide observations/notes as applicable.

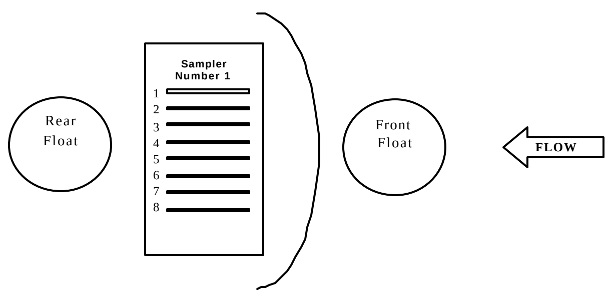
Sampler #1



Sampler #2



Sampler #3



Samples:	Sample ID #	Foil Wrap	Dry Ice	Comments
Chlorophyll a				
Ash-Free Dry Mass				
Ash-Free Dry Mass				
Ash-Free Dry Mass				

Notes

Sheet 3 of 3

Sample Label

Sample Label

Date:	Time:	Collected By:
Sampling Site:		
Sample Type:		
Test Required:		Preservative:

Completed Label

Date: **5/1/00**	Time: **13:30**	Collected By: J. Smith, F Henry
Sampling Site: **KRALG-001**		
Sample Type: **Artificial substrate: one glass slide**		
Test Required: **Chlorophyll a**		Preservative: **Foil wrap/Dry Ice**

Field Log

Sample identification				**Field Measurements**					**Sample Types**		
Field ID#	Site Name	Date (mm/dd/yy)	QA Type	Tw (C)	DO (mg/l)	Cond (uS/cm)	pH	Redox mV	Chl a	AFDW	Other
Remarks											
Project Name:_______________				Collected By: ______________________							
R - Regular Sample RB - Rinseate Blank B - Blank				S - Spike D - Duplicate							